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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

TROUBLES OF CEMA COMPUTER DEVELOPMENT DESCRIBED

Zurich NEUE ZUERCHER ZEITUNG in German 24 Jun 78 p 14

[Text] In 1969 the CEMA countries signed an international agreement providing for the development of a joint third-generation computer family with the designation ESER [uniform electronic data processing system]. This computer series is known also by the Russian designation "Riad." Altogether 300,000 workers and 20,000 scientists in more than 70 enterprises are involved in the development of the "red computer."

Imitation of Obsolescent Western Systems

So far these joint labors have brought the development of the computer generation ESER 1, which involves six central units and some 150 peripheral devices. This is basically an imitation of the obsolete IBM system 360 which has been slightly modernized. Nearing completion now is the development of the computer series ESER 2, described in Eastern publications as the "generation 3.5." Envisaged is the production of the following models: 1015 in Hungary, 1025 (CSSR), 1035 (Poland and the Soviet Union), 1045 (Soviet Union), 1055 (GDR) and 1065 (Soviet Union).

Actually the communist countries are imitating Western developments at long delays. This is documented by the fact that the production of micro processors, for example, will begin in CEMA only in the course of the next 3 years, following "joint efforts." That was recently announced by Professor Kubat, Czechoslovak Deputy Minister for Technological and Investment Development.

Joint Efforts

At the same time the CEMA countries are making greater and greater efforts to close the gap vis-a-vis the West. In 1975 Hungary, Cuba, Poland, Romania, the CSSR, the GDR, the USSR and Bulgaria set up a commission of experts which was to prepare proposals on how to emphasize computer training at the universities. The second meeting of this body took place recently in Szeged (southern Hungary). A report by the experts suggested familiarizing students of elementary and secondary schools with matters relating to cybernetics

and computer technology. To achieve this, teachers are to be instructed in these subjects at the pedagogical advanced schools. Also proposed was a new system for the training of specialists. Basic research in the field of electronic data processing is well developed in the communist countries. The problem arises in translating these achievements into production, let alone mass production. CEMA backwardness in the field of computer technology must, at least to some extent, be attributed to the fact that Stalin dismissed cybernetics as a "capitalist pseudo science." Right at the beginning of computer development, therefore, substantial arrears arose, which it is very difficult to make up at this stage.

Export Obstacles

At the same time the Eastern countries are now hard put to it in the computer field to purchase Western know how or even plant. The reason is that computers represent strategic goods, and the American Government must issue export licences if U.S. computer firms are involved. Moreover the Paris Committee for Coordinating East-West Trade must give its blessing to the export of computers to the East. Generosity is not the custom here. Export licences are often refused, especially for large-scale facilities. In addition major Western computer installations in the CEMA area must be supervised by Western experts to make sure that they are not used for military purposes.

Vienna--Principal Transmission Center

Nowadays Vienna is the most important transmission center for the export of Western computers to the CEMA region. All major computer manufacturers have branches there to trade with the CEMA countries. Also housed in Vienna is an Eastern computer at the Control Data Corporation (CDC); it is used for test purposes in conjunction with Western facilities. Involved is the model 1040 (ESER 1), produced in the GDR and supplied by the Dresden Robotron. CDC purchased this facility (which roughly corresponds to the IBM model 360/40) in 1974. The central unit works in conjunction with a Soviet card scanner and keypunch machine as well as various CDC peripheral devices.

Upon closer scrutiny it was noted that the Eastern devices are not mass produced. Evidently they still involve much manual labor. That is not surprising because, after all, labor is cheap in CEMA. The installations are also very much larger than in the West. Material consumption is not that important either. Nevertheless, due to lower productivity (and despite the lower labor costs), the total cost of production in the East is likely to be greater than for comparable Western computers which are manufactured exclusively by mass production methods on an assembly line.

Despite the development of CEMA computers and the lack of foreign exchange reserves in the communist countries, the top managers of the branches of Western computer firms established in Vienna appear quite optimistic about the further export opportunities in the CEMA region. They point out, in particular, that Western installations will be purchased for special

applications and high-priority projects. However, Western computers are likely to be used only in areas where Eastern facilities cannot cope, or when delivery delays for CEMA computers are unacceptable. The computer firms also complain about increasing pressure from customers in the red economic bloc for entering upon compensation transactions.

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MICROPROCESSOR DEVICES: ACHIEVEMENTS AND PROBLEMS

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 pp 1-3

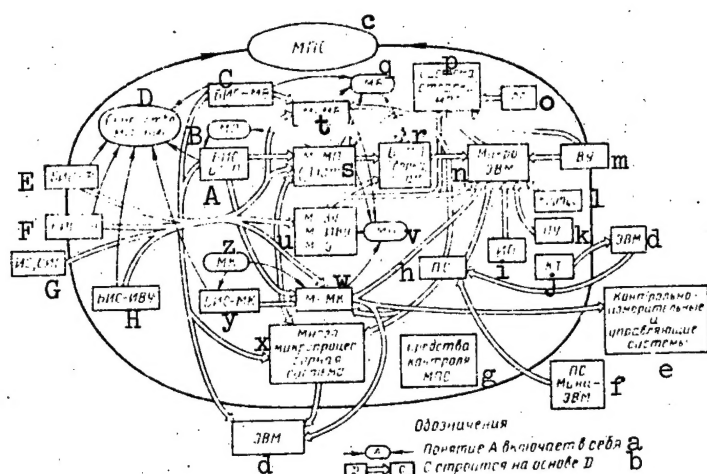
[Article by Academician E. A. Yakubaytis, Academy of Sciences, Latvian SSR, and Kandidat of Technical Sciences A. K. Baums]

[Text] The present article contains the main points from report [1], given at the Second All-Union Conference on Microprocessors, which dealt with the development of microprocessor devices in the period between the first and second conferences (1975-1977).

The computer technology of the 70's has a new technological basis, founded on the achievements of modern microelectronics, with its continually increasing level of integration. The effort to develop a functionally complete computer, or rather its electronic portion, on a single chip led to the concept of the microprocessor. The notion "microprocessor" does not have a single meaning, but rather has come to stand for a complex of hardware and software developments [2] which are designated microprocessors. The concept of "microprocessor device" and the complex interrelationships among the ideas included within the term are illustrated in the figure. The chief property of the microprocessor and of almost all the conceptions falling within the domain of microprocessor devices is that they unite within themselves both design and functional characteristics.

During the rather short period (about two years) which we will be considering, great progress was made in all aspects of the development of microprocessor devices as well as in the improvement and development of a multitude of new industrial methods for creating very large integrated circuits.

In spite of the great achievements of bipolar technology, the main technological basis is still p-MOS technology, and in spite of the evident merits of 16-bit microprocessors, 8-bit types are still preferred. Thus both third-generation microprocessors (Zilog Z-80, Intel 8085, Texas Instruments 9900) and 8-bit 2.5th-generation microprocessors (Electronics Arrays EA 9002, Fairchild F-8, Intel 8048 and 8748) utilize p-MOS technology.



(The concepts and devices included within the domain of microprocessor devices are located within the solid line. Hardware and software elements closely associated with microprocessor devices are placed outside the line. Circuits and devices which are functionally complementary to microprocessor devices, whether specially developed for the purpose or selected from standard components, are located on the boundary line.)

- r. Microprocessor block (assembly of PC boards)
- s. Microprocessor module (PC board)
- t. Microcomputer circuitry module
- u. Memory, interface and other modules
- v. Modular array
- w. Microcontroller module
- x. Multimicroprocessor system
- y. LSI microcontroller
- z. Microcontroller
- A. LSI central processor, processor
- B. Microprocessor
- C. LSI microcomputer circuitry
- D. LSI microprocessor family
- E. Functional LSI circuits
- F. LSI memory
- G. IC, MSI circuits
- H. LSI interface circuits

Third-generation microprocessors are characterized by their speed and high level of integration. The latter characteristic has made it possible to include within the large-scale integrated circuits (LSIC) of the central processor certain features which in the case of second-generation microprocessors were located in separate IC's. Thus the access time of the 8085 is 1.3 microseconds, compared with 2 microseconds for the 8080A. The 8085 chip includes a timer and a priority interrupt circuit, not included in the 8080A. The Z-80 chip includes 8200 transistors, and the 8080A only 4500.

LSI interface circuits have been successfully developed in third-generation microprocessors. All the major microprocessor families incorporate these. For example, the Intel Company has developed more than 10 different specialized and general-purpose programmable LSIC which act as floppy disk and display controllers, timers, direct memory access units and so on. As a result, with the transition to third-generation microprocessors during 1975-1977 the number of components in a system of medium complexity decreased from about 17 to 3 [3].

The development of 16-bit microprocessors with a single LSIC to serve as the basis for minicomputer processors has been extremely successful. A typical microprocessor of this type is the Fairchild 9440, incorporating the instruction system of the Nova minicomputer.

It is forecast that by the early 80's 16-bit microcomputers which contain 32 Kbyte of main memory in addition to the central processing unit (CPU) will be the most common type. It is expected that the late 80's will see a transition to 32-bit microcomputers with 100 Kbyte of main memory. All the leading developers of microprocessors are already preparing for these new stages.

In addition to general-purpose microprocessors, specialized 8-bit microprocessors of the 2.5th generation (with 1 or 2 LSIC), usually called microcontrollers, have undergone vigorous development. Single-chip LSI controllers (SCAMP, Electronics Arrays EA 9002, Intel 8048 and 8748, Mostek 38070 and others) include in a single LSIC all the necessary elements for autonomous control of the system: an arithmetic-logic unit (ALU), random-access memory (RAM), read-only memory (ROM) and interface circuits. Masking makes it possible to enter into ROM a program which specializes the controller for the performance of specific tasks. The functional capabilities of such controllers can be extended by adding additional LSI memory units and interface circuits. Such microprocessors are used, for example, in highly specialized products destined for large-series production.

The Intel Company's new 8-bit 8041 and 8741 microcontrollers are intended to perform operations with complex external units in microprocessor systems. By operating in parallel with the main microprocessor, they significantly decrease its load.

In addition to the traditional 4-bit and 8-bit controllers, 16-bit (Texas Instruments TSM 9940) and fast bipolar single-bit controllers (Signetics 8X300, with a cycle time of 250 nanoseconds) have now been developed.

The usual microprocessor architecture generally does not allow high-speed performance of linear arithmetic operations and other operations of a computational nature. Special functional LSI circuits have been developed for faster performance of these operations. For example, ADM manufactures a functional LSI circuit for rapid multiplication which can multiply 8-bit numbers in 450 ns and 16-bit numbers in 850 ns. Use of the ADM 9511 arithmetic processor, developed by ADM, makes possible a 50- to 100-fold increase in the speed of multiplication and division in fixed or floating point, square root extraction and the computation of exponents and inverse trigonometric functions by 8-bit microprocessors [4].

LSI microprocessors are becoming the universal basis for constructing various classes of computers. The performance of this task received considerable attention at the Second All-Union Conference on Microprocessors, at which the prospects for microprocessor development and the requirements for microprocessors to be used in the construction of different types of computers (microcomputers, minicomputers, control computers, general-purpose computers, recursive and interpreting computers) were discussed. At present the greatest speed and flexibility are realized by using processor chips. For example, the ATAS-16M minicomputer with microprogram control, a set of 129 instructions and 8 priority levels, which performs addition in 250 ns, is based on the 4-bit AM 2901 chip. The in-line conveyor type of architecture is used in it [5].

The conveyor principle offers the possibility of significantly increasing the productivity of computer systems without proportional increase in the number of microprocessors. Specialized LSIC's to increase the speed of performance of specific operations have been built using this principle [7]. The promise and the versatility of this principle are well illustrated in reference [6] and were discussed in reports given at the Second All-Union Conference on Microprocessors.

However, owing to the low cost and small size of microprocessors, the principles of parallel information processing which form the basis of multimicroprocessor systems are becoming most common. The question of utilizing them to increase the productivity and reliability of systems is of great current interest. Evaluation of the efficiency of such systems is of considerable significance. Efficiency is determined to a great degree by the organization of synchronization and information interchange between the microprocessors. Special matrix switching fields, trunk lines, or combinations of these approaches are used to organize such information exchange. The multilevel architecture of multiprocessor systems must be considered one of the main principles of their construction. Depending on the problem to be solved, distributed systems consisting of different types of microprocessors (UMASS, GALAXY/5 and others), each of which is specialized to perform a specific task, and multiprocessor systems which allow dynamic allocation of similar tasks, are being developed and applied. For example, an experimental model of the $\sqrt{C_m}$ system includes 10 LSI/11 microcomputers; 100 of these are planned for the complete system. Plans for systems of 1,000 microprocessors are being discussed [8].

The modular principle of microprocessor system development was used in first-generation microprocessors. The existence of standard modules considerably simplifies the user's tasks, since the main hardware problems are solved by the microprocessor manufacturers or companies specializing in the development of modular sets. Progress in the development of the modern manufacturing base makes it possible to treat as the basic modular element the individual printed circuit board, on which the entire electronic part of a functionally complete microcomputer ("naked" machine or microcomputer circuitry) may be housed. Such universal modules, containing a central processor, main memory, RAM, ROM and interface with all the main peripherals, are produced by the major microprocessor system manufacturers. Both 8-bit (Intel SBC 80/20, Motorola M68MMI) and 16-bit (Interdata 5/16, Texas Instruments 900/4) modules are being produced. Software as well as hardware is constructed on the modular principle.

Software development requires considerable labor expenditure and is one of the most pressing problems in the development of microprocessor systems. The resident programs in microprocessor devices usually include a simple monitor, editor and assembler. High level languages, which are extremely convenient in programming, are realized with the aid of cross-translators using minicomputers, large general-purpose computers or time-sharing systems. Small systems make use of cross-assemblers, which make it possible to obtain more economical programs. As a result, special software is developed to automate the process of developing assemblers for specific microprocessors, for example the SIGMEN assembler and imitator generator [9]. Such generators are extremely important in the specialization of microprocessor systems by the introduction of new instructions via the microprogram.

The most popular high level languages are those based on PL/I: PL/M, MPL, PL/Z, PL/6800 and so on. New promising languages include FORTH [10] and TLC [11], but traditional languages such as FORTRAN, COBOL and BASIC are also used. Recently these languages have also been used in resident software systems for microcomputers equipped with floppy disks. Software problems are simplified in systems using the command systems and architecture of popular minicomputers (LSI/11, Micro-Nova).

The method of coordinated development of hardware and software for microprocessor systems has found considerable favor with users. Accordingly all the main American LSI microprocessor manufacturers offer special microprocessor debugging systems for their microprocessors: Intel's "Intelec", Motorola's "Exorciser" and so on. Some firms offer universal units for all microprocessor systems: Signetics' TWIN, Millennium Information Systems' "Universal One" and so on. Sophisticated microcomputers with large RAM (64 Kbyte) and a wide range of peripherals (including display and floppy disk storage) have been based on debugging systems, making it possible to use resident compilers with the high level languages PL/M (Intelec) and Micro-BASIC (Universal) for debugging. These debugging systems are significantly simplifying planning and shortening system development time.

The range of applications of microprocessors is growing continuously. The reason is that microprocessor systems offer new possibilities for the solution of fundamental social problems: increasing labor productivity, decreasing energy use and preventing environmental pollution. Microprocessor devices are finding widespread utilization and are becoming a part of human life. Questions related to the incorporation of microprocessors were extensively discussed at the Second All-Union Conference on Microprocessors. The requirements governing microprocessor applications in various sectors and the ways of satisfying them with domestically-produced and the most popular foreign microprocessors were analyzed and new structures for the development of specific systems were proposed.

The vigorous development of microprocessor devices and their practical application have left many theoretical problems unsolved. These include questions of scientifically-based selection of microprocessor and microprocessor system architecture and the selection of the optimal microprocessor type for a specific system. The problem of standardization and unification of microprocessor hardware and software has become a pressing one, as has the necessity of developing terminology for this new and rapidly developing branch of science and technology.

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THE ORGANIZATION OF DATA BANKS FOR FUNCTIONAL SUBSYSTEMS OF A SECTORIAL AUTOMATIC CONTROL SYSTEM

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 pp 7-9

[Article by Engineer M. A. Appak: "The Organization of Data Banks for Functional Subsystems Within ASU-Pribor"]

[Text] The purpose of this article is to describe the data bank which is used to provide information and software support to a subsystem of an OASU [sectorial automatic control system]. At present, there are a number of factors placing limitations on data banks. These include insufficiency of working memory and direct-access facilities, weak operating-system capabilities, and an awkward classification of the indicators which are used. Thus it would be expedient to develop data banks whose generality of application would be determined by circumstances. In my opinion, the main characteristics of such data banks would be: information modeling of a portion of sectorial management and assurance of flexible cooperation between data banks.

The subsystem for management of the financial activities of the sector [1] is part of ASU-Pribor [instrument-making industry automatic control system] and currently includes 23 tasks. Most of the indicators used in the tasks of the financial subsystem are specific to that subsystem. The data bank constructed for the subsystem is oriented toward the disk operating system of a unified system and does not envision any additional expansion of the operating system. This characteristic allows the data bank to be used on any unified computer system, starting with the YeS-1030 with the standard hardware array. Operation of the data bank requires 3 magnetic disk storage units and 2 magnetic tape storage units. The volume of working memory used is about 200 Kbyte.

The data bank is based on PL/1, the base language of the system, and includes open and closed system options. Utilization of a subset of PL/1 for all internal microinformation purposes has been found to be satisfactory. Additional procedures make it possible to execute a number of non-program types of access and have made additional CALL options available to the programmer.

The data bank includes all information necessary for the performance of the tasks of the subsystem; it is centrally organized in a specific structure, is

updated and revised, and also offers the possibility of interchange of information among the tasks of the subsystem, output of information to other subsystems, elimination of redundancies, unified access, an inquiry-response mode of operation with non-program access, logical processing of information, self-monitoring and data protection.

The data bank is not a rigid system. Basically all necessary changes can be introduced via a reference system. But in case of significant fluctuations in the input or output stream, it is necessary to add on new procedures which are fully program-controlled. Updating and revision of the data make use of the same features. An extremely important matter is the organization of information exchange within the subsystem. The critical point is that the tasks of the subsystem are informationally interrelated. The total quantity of input data amounts to about 30 percent of the calculated indicators, and the primary information utilized to about 20 percent. The data bank provides for automatic interconnection of the tasks performed in the subsystem.

The data bank has a definite internal organization. Its basic structural unit is the economic indicator. At present about 160 primary indicators, with specific numerical values, are used, i.e. 160 dimensions. Operating experience indicates that the performance of new tasks can be conducted largely on the basis of existing information. The storage of all necessary information is combined with a capability of direct access to it, since it is used not only to perform specified tasks but also in the inquiry-response mode. In addition, data stored over a long period are frequently utilized in external logical processing and aggregation, as well as for the control of circulating information.

There has been no requirement for organization of the indicators into a classificatory scheme, and accordingly the financial indicators which are used are arranged in a single sequence. However, this does not mean that the data bank excludes the possibility of expressing classificatory relationships: each indicator is physically separable. Only two parameters, which have extensive quantitative interpretation and are critical in identification, are not fixed: time and facility (supplementary parameters). The measurement units are equalized by buffer software. Each item can be conventionally represented by a point in 3-dimensional space whose dimensions are: the indicator, the facility and the time period. The smallest time unit is the ten-day period. Monthly, quarterly and annual periods are also used. Facilities include all possible sectorial subdivisions: industrial enterprises, production associations and all-union industrial associations. In principle, other parameters could also be allowed to vary.

The largest portion of the data base consists of files corresponding to economic indicators (Group 1). These include the source data and regularly used computational data. The data base also includes reference system files (Group 2), pre-bank files (Group 3) and aggregation files (Group 4). All of the files in groups 1 and 2 are index-sequential. The files in Group 3 are sequential and index-sequential, and those in Group 4 are sequential.

The index-sequential files allow both sequential and direct access. Their use makes it possible to introduce local changes and makes for rapid and convenient program interaction. As is well known, when the index-sequential file is made up the entries are located in the data section, while the overflow section is used during updating. Generally, 20 percent of the file area is assigned to overflow. The utilization of special start procedures which allow the entering of a relatively constant group of keys leads to savings of RAM and decreases the number of file reorganizations. An index-sequential file can be modified many times through new keys, and the advantage of direct access will not be lost in the process. An indicator of the necessity of keeping free of accumulated "rubbish" is the exceeding of the control digits for access to the overflow areas. A 4-byte facility code serves as a key in all Group 1 files. The size of the entry in the main data area is 8 bytes: 4 bytes for the accounting period code and 4 for the indicator value. The 4-byte accounting period code consists of conventional codes for the year (2 bytes) and the period of the year (2 bytes).

It is logical to consider the entries in such files as a group of structures, each consisting of 2 parts: a 4-byte symbolic string for identification of the data and the 7-figure numerical value of the indicator, packaged in 4 bytes. The data are not packaged for convenience of processing.

In most of the reference files the key is a 6-byte information source code or the 4-byte code of the Group 1 files. The Group 3 sequential file serves to protect the data bank and to unify the entering of information into the Group 1 files. It consists of entries containing the information source code, the period of the year, the facility and the datum itself.

The Group 4 files are formed through performance of the tasks of the subsystem. Their entries consist of the codes for period of the year, facility, auxiliary identification parameters, and up to 16 aggregated indicator values.

The following information storage periods are specified for Group 1: 4-20 months for 10-day indicators; 1-5 years for monthly figures; 3-6 years for quarterly figures; 6 years for semiannual figures; and 12 years for annual figures. Information in Group 4 is preserved for 10 days to 3 months.

Data Bank Software

The data bank programs consist of 5 blocks. Block B1 contains the procedures for input into the pre-bank area. This block is constructed to allow the processing of information recorded on various media in a wide variety of formats and also from any output file of Group 4. The structure of the procedures is modular, which makes possible a sufficient level of unification. All the programs in Block B1 are designed to utilize three reference files. The first file indicates what kind of information, in what kind of format, string or array, should be entered in the data bank under the given datum. Another file indicates the files in the data bank to which arriving data should be assigned and how long it should be stored. By means of the third file, which contains information about the labels of files in disk storage, the auxiliary file on magnetic tape which is required for the operation of the procedures in Block B2 is formed.

Through the performance of the procedures in Block B2, information is entered into storage, updated, revised and checked. The control procedures have an important role in blocks B1 and B2. In addition to the traditional methods of assuring maximum purity of the incoming information--checking of control sums, inadmissible symbols, keys--special methods are also used. These include monitoring of the completeness or redundancy of incoming data, sense control (through value "branchings"), and balance methods. Block B2 includes procedures for checking the dynamic characteristics of indicators as well as procedures for calling supplementary information and carrying out alternative aggregation variants.

Block B3 includes procedures for inter-system exchange. One of these is the main procedure, and the others are set up for specific media and structures of the transmitted data. Where necessary, these procedures can be transformed in response to an altered information flow. This process is fully regulated.

Block B4 consists of the service routines: the start routines, reorganization programs and reference system programs. A special place among the reorganization procedures is held by those which provide "correction" of stored data through alteration of facility codes, the combination of several enterprises into a large facility or the subdivision of facilities into smaller ones.

Block B5 contains procedures for interaction with the data base in program or inquiry-response modes. These are procedures which are employed by programmers as the main information functions when they write programs in the PL/1 language. The main purpose of these procedures is that of providing various alternatives in the reading or shifting of information from the data base and its translation into a structure which is suitable for a given type of task. The main data which are transmitted in this procedure are: dates, facilities (as constants or variables), numbers of complexes, file names and input structures (2- or 3-dimensional). The programmer has the capability to expand the area of application of these procedures by using parameters external to the programs, including various types of computational operations and specific sets of facilities. The programmer is relieved of the necessity of knowing the sources, structure, location and movement of data. The operator is able to designate specific modes of computer operation.

The procedures in the inquiry-response mode have a more complex organization. In this case manipulation is purely parametric and is carried out on the non-program level. The user may inquire about any indicator stored in groups 1 or 4. In addition he may utilize information from the reference system. The inquiries are input into the system via punchcards or a keyboard. The user may present about 50 inquiries in a single run. There are specific types of inquiry which allow the user to obtain information for any time period. Let $\{Q_i\}$, $1 \leq i \leq n$, $n \geq 1$ be the facilities, $\{t_j\}$, $1 \leq j \leq m$, $m \geq 1$ be the time periods and $\{p_k\}$, $1 \leq k \leq e$, $e \geq 1$ be the indicators.

In addition, let P , Q , T be random sets and $P \subset \{p_k\}$, $Q \subset \{Q_i\}$, $T \subset \{t_j\}$. We will call P , Q and T "inquiry actions." Let the sign $\&$ indicate simultaneous actions.

Then any expression $P \& Q \& T$ is a permissible inquiry. It is read as follows: "For the set of indicators P , for the specific facilities Q , for the time period P ." For example, "the actual net income" or "the plan for consumer product output" for the enterprises of the SAM plant (Ryazan'), the Mosrentgen plant (Moscow) or the Soyuztochmashpribor all-union association, for the first quarter of 1976 or for June 1976.

A typical case is that in which one of the acts is complete, i.e. $Q = \{Q_i\}$, $T = \{t_j\}$. This situation is handled on the parametric level so as to spare the user unnecessary enumeration. In addition, the sets $\{Q_i\}$ and $\{t_j\}$ are themselves divided into natural classes in terms of which inquiries may be formulated: for example an inquiry for a certain industrial association or for all the data of a certain year. The inquiry-response mode provides a way of gradually making the user's requests more specific.

In the case where one or two of the actions are general and the others specific, it is helpful to subdivide the inquiry into several partial inquiries so as not to obtain unnecessary information.

For indicators in Group 4, the inquiry actions T always have just one value.

Besides the above functional capabilities, the data bank provides for the processing of closely associated indicators. For example, for normative indicators it can show percentages of the norm or the values not only of the actual indicators, but of the planned ones as well. The number of such associations recorded in the reference system is small. They can be taken into account in responses to inquiries at the option of the user.

Responses are intentionally made in tabular form. As a rule, the inquiries are intended to locate data during systematic analytical and planning work. In such cases there is no need for a high level of efficiency, the more so because the responses must sometimes be kept for long periods. The general structure of the data bank is shown in the figure.

Prospects for the Development of the Data Bank

We shall consider several aspects of these prospects: technical, programming and information.

At present the data base contains about 160 Group 1 indicators and roughly the same number in Group 4. The entire data base occupies about 18 Mbyte of direct-access memory. Without increasing the number of magnetic disk storage units used it would be possible to add about 50 Group 1 indicators and about 100 Group 4 indicators to the data. Thus, the technical realization of the data bank provides for a certain expansion within the existing configuration. Its further expansion entails recognition of the fact that the number of direct-access memory units would surpass the number which is typical for most of the tasks in ASU-Pribor. This circumstance may act to retard effective work in the multi-program mode. It is true that the data base is in a saturated state in terms

of the classes of tasks employed in the subsystem. The introduction of new tasks into the subsystem would not significantly increase the number of Group 1 indicators. At the same time, the characteristics of the technical realization that have been described contribute to a certain limitation of the sphere of activity of such a data bank. The user must determine the volume of information with which he will need to work.

The software of the data bank described above makes it a fairly flexible information system. However, there remain unsolved problems, for example the creation of more flexible modular structures for operations with the data base, the construction of an external language system for parametric uses, and also problems associated with setting up the system on more powerful operating systems, for example that of a unified-system computer. The utilization of unified-system operating systems might make it possible to decrease significantly the program block of the data bank, to compress the data base itself, and to unify parametric interaction.

An essential matter is the improvement of the data-description language. In my opinion, this aspect of the development of the data bank can be extremely productive and versatile.

It is expedient to incorporate a classification of the accumulated indicators in the reference system. The user should not be obliged to make his inquiries about indicators fully specific when it is possible to proceed less formally. This is important in cases where there is no clear conception of the situation which is being clarified.

The development of formal modes of aggregation logic is promising. At present the user's information needs are confined by a clumsy and rather rigid structure of output forms. About 20 percent of the aggregated indicators are redundant; this results from the fact that various forms of financial management work lead to different methods for utilizing the same indicators.

It has been proposed to output a predetermined set of data in a standard output format. This is not always justifiable. The depth of one or another effort may depend to a considerable degree on the user hierarchy, and this should be reflected in the data banks.

Each of the essential tasks actually contains several smaller ones. Among these subtasks, the shared nature of many operations which are typical of financial analysis and planning has been well examined. The structure of the analytical tasks has received rather detailed examination in the literature [2]. The production of standard processing modules, and later of procedures for their interconnection, may allow the introduction of an element of formalization in the assignment of tasks. The possibility of modeling the management process more precisely, and even of introducing a greater systematization into the accounting process, offers itself.

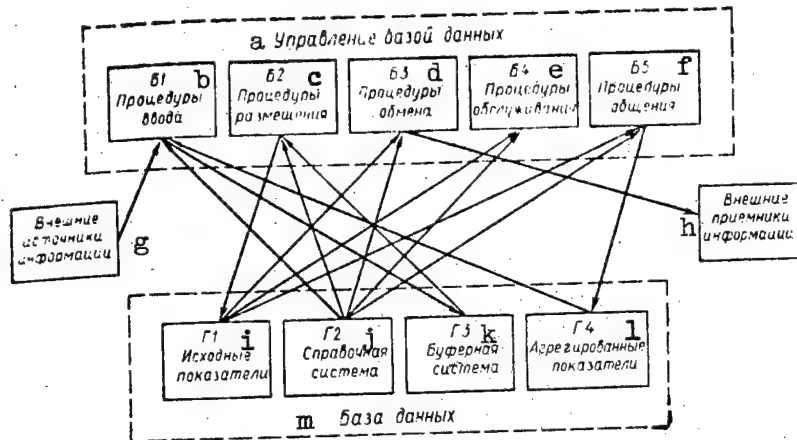


Diagram of the Data Bank

- Key:
- | | |
|--------------------------------|-----------------------------------|
| a. Data base management | h. External data receivers |
| b. Input procedures (B1) | i. Group 1: initial indicators |
| c. Allocation procedures (B2) | j. Group 2: Reference system |
| d. Interchange procedures (B3) | k. Group 3: Buffer system |
| e. Service procedures (B4) | l. Group 4: Aggregated indicators |
| f. Interaction procedures (B5) | m. Data base |
| g. External data sources | |

Conclusions

1. This data bank variant is based on the technical facilities of a unified computer system and disk operating system.
2. The data bank performs the reception, logical processing and storage of economic indicators needed to perform tasks in the subsystem. It provides the user with a system for management of information flows.
3. The data bank contains parametric and program facilities which gave the programmer broad capabilities in his work with the data base.
4. The data bank may operate in the inquiry-response mode, through which, by indicating specific parameters, it is possible to obtain information on any facility which is represented in the data base.
5. The data bank can be adapted to utilization in other subsystems of OASU, for example in the subsystems for technical-economic planning, operational management, and technical support of production.
6. Limitations on the utilization of this type of data bank result from the volume of information and the variety of indicator types. It is most expedient to use this data bank for intermediate volumes of information (up to 20 million bytes per year) and with analytical and planning elements in the subsystem model.

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THE EQUIPMENT COMPLEX OF THE UNIFIED SYSTEM FOR TELEPROCESSING OF DATA

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 pp 9-12

[Article by Engineer V. B. Bespalov and Kandidat of Technical Sciences G. M. Strizhkov]

[Text] Purpose

The unified system for teleprocessing of data (YeSTYeL) is a complex of hardware and software elements oriented toward the collective utilization of electronic computers by several individual users. The YeSTYeL equipment complex is designed for teleprocessing of information and gives individual users who are equipped with subscriber points access to the computer.

Communication between the subscriber points and the computer is carried out via telephone and telegraph channels and also by physical lines. The utilization of data transmission equipment allows an almost unlimited distance between the computer and the subscriber point. Through direct access to the computer, the user is able to send information to it for processing and to receive information in return. Considering the allowable response delay, the productivity of the computer and the speed of data transmission using the YeSTYeL equipment complex, it is possible to develop systems which operate on a real-time basis. The information processed by the YeSTYeL complex can be of various types.

The YeSTYeL equipment complex also makes it possible to carry out decentralized collection of information in all cases where centralized management of territorially distributed facilities is required; it can work with one of the compatible computer models of the unified system (YeS-1020, YeS-1022, YeS-1033, YeS-1040, YeS-1050 and others). The YeSTYeL complex is connected to the computer's multiplex channel. The number of subchannels and the amount of working memory depend on the number of lines (communications channels) controlled.

With a maximum of 64 lines, the working memory of the computer must be at least 128 Kbyte, and with 32 lines it must be 64 Kbyte. The amount of memory also depends on the number and type of terminals connected, the number of terminals operating simultaneously, the mode of operation of the system, the productivity of the computer and so on.

Makeup of the Complex

The YeSTYeL equipment complex contains the following units: the MPD-1 (YeS-8401) data transmission multiplexer; a group of IZOT-401 linear converters; various types of subscriber points (terminals): AP-1, AP-62 (YeS-8501--a general-purpose terminal for batch processing and interactive information interchange; YeS-8562--an interactive video terminal; T-63, T-100 telegraph apparatus); modems with various transmission rates (YeS-8001, YeS-8005); and UPS-TG (YeS-8030, YeS-8033) and UPS-IY (YeS-8027) signal conversion units.

The YeSTYeL equipment complex may be expanded by the incorporation of new units.

Configuration

The user of the YeSTYeL equipment complex receives it in the required configuration. For employment by industrial enterprises in automatic data processing systems, two configurations are recommended, as shown in the table.

1 Устройство	Конфигурация 2		1 Устройство	Конфигурация 2	
	3 I в ед.	4 II в ед.		3 I в ед.	4 II в ед.
МРД-1, ЕС-8401	5	1	АП-62, VTS-56100	10	4
Шкаф ИЗОТ-401	6	1	Модем BC-8001-03	11	6
АП-1, ЕС-8501	7	1	Модем ЕС-8005-05 (03)	12	9
АП-1, ЕС-8501-01	8	1	УПС-ТГ, ЕС-8033	13	1
АП-1, ЕС-8501-03	9	3			

- | | |
|---------------------|----------------------------|
| Key: 1. Unit | 8. AP-1, YeS-8501-01 |
| 2. Configuration | 9. AP-1, YeS-8501-03 |
| 3. I: no. of units | 10. AP-62, VTS-56100 |
| 4. II: no. of units | 11. YeS-8001-03 modem |
| 5. MPD-1, YeS-4801 | 12. YeS-8005-05 (03) modem |
| 6. IZOT-401 frame | 13. UPS-TG, YeS-8033 |
| 7. AP-1, YeS-8501 | |

Concise Technical Specifications of the Complex

The MPD-1 (YeS-8401) data transmission multiplexer is designed to control the computer multiplex channel and connect it to the communications lines through linear converters. It has a start-stop mode of operation and contains the following adapters: a TA-1 for control of start-stop printer terminals; a TA-2 to control teletype on 2-wire Telex lines; a TA-3 to control video terminals in the start-stop mode on 4-wire dedicated channels.

The speed of transmission is 50, 75, 100, 200, 600, 1200 and 2400 bits per second.

The multiplexer is designed for use on the following types of channels: switched and dedicated 2-wire telephone; dedicated 4-wire telephone and telegraph; switched and dedicated 2-wire Telex; 2-wire and 4-wire direct physical lines with low signal level. The number of usable lines is: up to 32 for the TA-1 and TA-2 adapters for T-63 and T-100 terminals at speeds of 50, 75, 100, 200, 600 and 1200 bits per second; up to 64 with TA-3 adapters for YeS-8561, YeS-8562, YeS-8563 and YeS-8564 video terminals at speeds of 600 and 1200 bits per second; up to 32 with TA-3 adapters for YeS-8561, YeS-8562, YeS-8563 and YeS-8564 video terminals at a speed of 2400 bits per second; 31 lines for TA-1, TA-2 and TA-3 adapters for YeS-8501, YeS-8570, T-63 and T-100 terminals; 32 and 16 lines respectively for speeds of 600/1200 and 2400 bits per second using the YeS-8561, YeS-8562, YeS-8563 and YeS-8564 terminals.

The multiplexer has several operating modes:

automatic calling of terminals on switched telegraph and Telex lines with speeds of 50, 75 and 100 bits per second;

operation on dedicated 2-wire telephone lines at speeds of 50, 100, 200, 600 and 1200 bits per second, on 4-wire telephone lines at speeds of 600, 1200 and 2400 bits per second, on 2-wire Telex lines at speeds of 50, 75 and 100 bits per second, and on 4-wire telegraph lines at speeds of 50, 100 and 200 bits per second;

operation on 2-wire and 4-wire dedicated lines at speeds of 50, 75, 100, 200, 600, 1200 and 2400 bits per second;

operation with one of two computers by means of two-channel switching, or simultaneously with two computers with dynamic (program) switching.

The IZOT-401 grouped linear converter assembly is designed for the assembly of converters of all types at the computer end; it has built-in instrumentation for monitoring of the communications channels and the linear converters; it has a capacity of up to 32 linear converters of types YeS-8001, YeS-8005, YeS-8030 and YeS-8033. An arbitrary array of converters may be used, depending on the configuration of the complex.

The YeS-8001 modem operates at a speed of 200 bits per second in a semiduplex mode on telephone lines; it is a composite unit which performs the following operations: conversion of digital signals into analog; provision of preliminary connection; inclusion of manual and automatic responses; automatic communication between subscribers via the general telephone network.

The YeS-8001 modem can be combined with the YeS-8061 automatic calling unit (ACU). In this case the two units count as a single design unit.

The YeS-8001 has the following design variants for different types of use:

the YeS-8001 self-contained modem without ACU, designed to operate on a non-switched telephone channel;

the YeS-8001-01 panel-type modem without ACU, designed to operate on non-switched telephone channels;

the YeS-8001-02 self-contained modem with ACU, used as a separate unit with the MPD-1 multiplexer when the IZOT-401 frame is not specified;

the YeS-8001-03 panel-type modem with ACU, designed to operate on switched telephone lines.

The YeS-8005 modem operates at a speed of 600 or 1200 bits per second in the duplex mode on 4-wire dedicated telephone lines (with video terminals); in the semiduplex mode on 2-wire dedicated telephone lines (with terminals); and in the semiduplex mode with a built-in TeS-8061 ACU on switched 2-wire telephone lines (with AP-1 units).

Depending on the type of use, the YeS-8005 modem is available in the following design variants:

the YeS-8005 self-contained modem without ACU, employed as a separate unit with the MPD-1, when the IZOT-401 frame is not specified;

the YeS-8005-01 panel-type modem without ACU;

the YeS-8005-02 self-contained modem with ACU;

the YeS-8005-03 panel-type modem with ACU;

the YeS-8005-04 self-contained modem without ACU, designed to operate without a return channel;

the YeS-8005-05 modem, similar to the YeS-8005-04, but of panel type.

The Ye-8030 telegraph signal converter is intended to convert digital signals to telegraph signals, operating at a speed of 50, 100 or 200 bits per second on 4-wire (non-switched) telegraph lines.

The YeS-8030 performs the preliminary connection procedures when a non-switched telegraph network is used. Depending on the nature of employment, the YeS-8030 is available in two design variants: panel type and self-contained unit, to be used with the MPD-1.

The YeS-8033 telegraphic signal converter is designed to work at speeds of 50, 75 and 100 bits per second on 2-wire switched telegraph (Telex) lines. It connects a computer using an automatic telegraph station with remote subscribers using T-63 and T-100 telegraph apparatus. The YeS-8033 is available in two design variants, as in the case of the YeS-8030.

The AP-1 (YeS-8501) user point is a start-stop type terminal with the following basic parameters:

the KOI-7 code, with one start and one or 2 stop messages and a parity bit, has a 10- or 11-bit structure;

the YeS-6191 punched tape reader operates at a speed of 10-27 characters per second;

the YeS-7173 typewriter (I/O unit) operates at a speed of 10 characters per second;

a built-in unit provides matrix error protection;

the interchangeable YeS-8001, YeS-8005, YeS 8030, YeS-8033 and YeS-8027 linear converters offer a wide range of transmission speeds (50, 100, 200, 600 and 1200 bits per second);

operating modes: organized automatic, direct connection to computer, mixed;

operating algorithms: point-to-point, multipoint connection;

data processing modes: remote batch processing, interactive.

Depending on the type of application, the AP-1 (YeS-8501) point is available in the following terminal types:

YeS-8501(00) terminal without linear converter;

YeS-8501-01 terminal, designed to work on dedicated and switched telephone lines with the YeS-8001 at a transmission speed of 200 bits per second and with a built-in ACU (YeS-8061) and a TA-3100 telephone apparatus;

YeS-8501-02 terminal, designed to operate on 4-wire dedicated telegraph lines with the YeS-8030 unit, at a speed of 200 bits per second;

YeS-8501-03 terminal, designed to operate on dedicated and switched telephone lines with the YeS-80005 modem at a transmission speed of 600/1200 bits per second, with a built-in ACU (YeS-8061) and a TA-3100 telephone apparatus;

YeS-8501-04 terminal, without linear converter and with a typewriter carriage width of 46 cm;

YeS-8505-05, YeS-8505-06 and YeS-8505-07 terminals, designed for the same conditions as the YeS-8501-01, YeS-8501-02 and YeS-8501-03, differing only in the carriage width (46 cm) of the W-529 Soemtron electric typewriter.

The VTS-56100 (YeS-8562) video terminal is a cathode-ray tube terminal with a Consul typewriter; the information is input using an alphanumeric keyboard.

The CRT screen format is 80x12 or 64x16 characters. The typewriter can type 80 or 60 characters per line. Information interchange is effected using the

KOI-7 code. The YeS-8562 video terminal is connected with the line by a YeS-8001 or YeS-8005 modem; operating mode (response) [as published]; addition or deletion of character or line.

Test programs operating under the control of the DMEC diagnostic monitor are available as part of the YeSTYeL complex.

The test programs for the MPD-1 multiplexer include 6 units for the checking of all instructions and functions. In addition to these tests, the OLTEP test programs can be conducted under the control of the DMEC.

The test programs for the AP-1 user point are performed in 4 stages. Reliability indicators may be checked during testing of operation of the AP-1. These tests provide local and remote testing of the components and of the system as a whole.

Operating Algorithm of YeSTYeL

The YeSTYeL has two configurations for the connection of user points to the communication lines: point-to-point and multipoint connection.

In the point-to-point configuration (Fig. 1) an individual terminal is connected to a specific data channel of the MPD-1 multiplexer via the line. This hookup can be effected in the YeSTYeL complex through switched or non-switched telephone or telegraph channels (lines). The point-to-point configuration with the AP-1 user point makes possible the following operations: calling, "point-to-point," "competition," "line-by-line dialog," "control of state." The calling operation is achieved by construction of a data channel, and the "point-to-point" operation by interchange of data between AP-1 and MPD-1 units. The use of the "competition" operation allows one point in the point-to-point configuration which has earlier been activated for data transmission to block the other. Performance of the "line-by-line dialog" operation makes it possible to develop interactive terminal systems, while the "control of state" operation is the selection of a specific terminal and its connection to the communication channel for interchange of data with the MPD-1 multiplexer.

The point-to-point configuration used with telegraph apparatus allows the calling and "point-to-point" operations. In this case the calling operation is similar to that using the AP-1, while the "point-to-point" operation is carried out in the "apparatus semiduplex" mode, i.e. by transmission of data in one direction only.

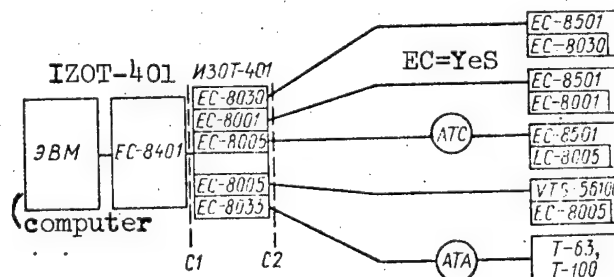


Figure 1.

Used with the VTS-56100 (AP-62) video terminal, the point-to-point configuration makes possible the performance of the "control of state" operation, which includes two suboperations: interrogation, consisting of interrogation of the video terminal as to the presence of data for transmission to the MPD-1 multiplexer; and addressing, during which the video terminal is made ready to accept data from the MPD-1 multiplexer.

The multi-point connection configuration has two modifications: in the first, the connection is made on the S1 interface level (Fig. 2), and in the second it is made on the S2 interface level (Fig. 3).

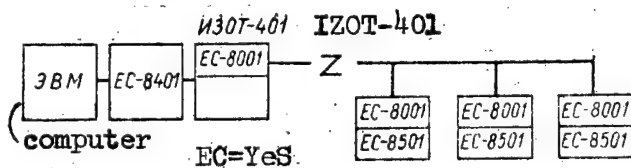


Fig. 2.

The multi-point connection configuration with the AP-1 unit allows performance of the "competition" and "control of state" operations. The "competition" operation in this configuration is fundamentally similar to the operation of the same name in the point-to-point configuration. The "control of state" operation is broader than its counterpart in the point-to-point configuration, as a result of the introduction of three special interpretations of the home address field in the "addressing" operation.

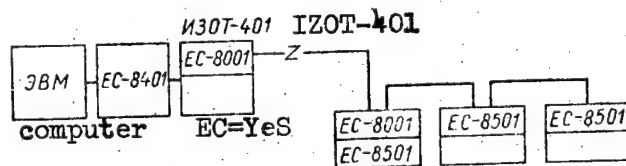


Fig. 3.

The multi-point connection configuration with VTS-56100 (AP-62) video terminals allows performance of only one operation: "control of state," which is fundamentally similar to its counterpart in the point-to-point configuration.

YeSTYeL Software

The YeSTYeL software includes:

supplements to the DOS/Yes [Unified-System Disk Operating System], Version 2.1 (methods of telecommunications access); and applied program packages.

Incorporation of the basic telecommunications access method (BTAM) requires a minimum of 64 Kbyte of working memory and 2 YeS-5052 magnetic disk memory units. The use of this method makes possible the control of YeS-8501,

YeS-8570, YeS-8561, YeS-8562, YeS-8563 and YeS-8564 terminals and of teletypes, the generation of the necessary channel programs, the processing of input-output interrupts, the control of communications lines, statistical error processing, and the organization of buffers for input and output of data.

Installation of the queued telecommunications access method (QTAM) also requires 64 Kbyte of working memory and 2 YeS-5052 magnetic disk memory units, and makes possible control of all the terminals enumerated in the description of BTAM. As its name implies, QTAM consists of control and processing programs. Installation of QTAM makes possible performance of all the operations characteristic of BTAM and also maintenance of priority in the input and output of data and the processing of user tasks.

For specific applications the user draws up applied programs, making use of the BTAM and QTAM macroinstructions. Three packages of applied programs are available with the YeSTYeL system: the dialog terminal system (DTS), the administrative terminal system (ATS) and the information flow control system (SUIP).

The dialog terminal system, which is a supplement to the DOS/YeS, allows operation in the time-sharing mode. The system is designed for simultaneous control of 31 remote terminals, requiring a minimum of 64 Kbyte of working memory. The two high-level programming languages PL/I and BASIC are available to the user.

The administrative terminal system is a supplement to the DOS/YeS and is designed for the storage, editing, updating and reproduction of text documents. The ATS requires a minimum of 64 Kbyte of working memory, and the system can control a large number of AP-1 terminals.

The information flow control system is a supplement to the DOS/YeS and makes possible control of a large number of terminals. A minimum of 48 Kbyte of working memory is required. The user programs are written in the Assembler language using the SUIP macroinstructions.

Conclusions and Recommendations

Experience with the YeSTYeL complex affords the following conclusions:

1. The YeSTYeL data teleprocessing complex is applicable in systems for automated data processing and transmission.
2. The YeSTYeL complex is capable of operating with the standard unified computer system software (DOS/YeS Version 2.1), including the QTAM telecommunications access method, and also with the ATS, DTS and SUIP applied software packages.
3. The components of the YeSTYeL complex are recommended for combined utilization in interchangeable configurations tailored to the needs of specific users.

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CURRENT TECHNOLOGICAL AND ECONOMIC RESEARCH TRENDS

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[Article by V. L. Chepurenko, Chief of the Planned Economy Administration, Ministry of Instrument Making, and Kandidat of Economic Sciences N. I. Buzova: "Main Trends of Technical and Economic Research in the Instrument Building Sector During the Tenth Five-Year Plan"]

[Text] An important role in the performance of the main tasks of the 10th Five-Year Plan, that of increasing the efficiency of social production and improving by every possible means the quality of work at all levels of the national economy, must be played by correct organization and a qualitatively new level of technical and economic research (TEI).

The main requirements for technical and economic research in the present stage are: comprehensiveness: it must embrace all aspects of the economic activity of all the structural subdivisions at the various levels of sectorial management; systematic character, determined on the basis of party and state decrees, and specific character; and the organic combination of methods of technical and economic research with automated control systems (enterprise and sectorial). In keeping with the above, in late 1975 the sector developed, and in early 1976 approved, a comprehensive plan for technical and economic research during the 10th Five-Year Plan. The preliminary plan was discussed and approved by the section on "development of the Instrument Building Industry" of the Scientific and Technical Council and by the board of the Ministry of Instrument Making.

The aim of technical and economic research in this sector during the five-year plan is that of guaranteeing the best conditions for fuller satisfaction of the requirements of the national economy for the products of instrument making, while simultaneously **improving** their quality and increasing production efficiency. To realize these goals, technical and economic research is to be carried out in the following main directions:

1. Analysis of the results of production and operations experience of enterprises and associations and development of recommendations for the further improvement of production efficiency;

2. Development and improvement of the normative base for planning and management of production;
3. Improvement of price determination;
4. Improvement of cost accounting principles of operations management;
5. Management of scientific and technical progress.

These directions constitute the basis for improvement of sectorial management on the basis of ASU-Pribor, Stage III [automated management system for the instrument making industry]. To assure a closer connection between economic research and the complex of efforts involved in the development of Stage III of ASU-Pribor, all work has been concentrated in a single organization: VNIPI OASU [All-Union Scientific Research and Planning Institute for Sectorial Automated Management Systems] (Moscow). This makes it possible, by bypassing intermediate departments, to effect in practice a fuller combination of economic science and mathematical apparatus based on third-generation computers.

We will consider how the attainment of these goals is being fostered.

Efforts in the first-named direction are making it possible to evaluate the results that have been obtained, to identify the most progressive developmental trends of the past period, and to analyze the causes of deviations in the activities of individual VPO's [all-union production associations] and enterprises.

Work of an analytical character is subdivided into interassociation (interplant) comparative analysis, multifactorial regression analysis and comprehensive analysis of the activities of individual enterprises.

Interassociation and (within VPO's) interplant comparative analysis is carried out by comparing individual technical and economic indicators of individual production units. Both qualitative and quantitative indicators are compared. Among quantitative indicators we may cite those characterizing the size of the associations or enterprises, such as volume of commodity production (or sales volume), the number of production personnel, the size of the wage and economic incentive funds, the fixed industrial assets and circulating capital, production costs of commodity output (or output sold), profit from industrial activity, and net profit. Qualitative indicators include labor productivity and plan intensity, capital-labor ratio, capital-output ratio, expenditure per ruble's worth of output, profitability (overall and effective) and so on.

It is extremely important to reduce all indicators for the period under analysis to comparable forms for the purpose of evaluating products and the component enterprises of VPO's, production associations and NPO's. Analysis makes it possible to identify which enterprises are working well and which unsatisfactorily. The extent of deviation from the average and its causes are identified by deeper technical and economic analysis carried out using traditional methods, for example indexes, statistical groupings, statistical analysis of series and so on.

Multifactorial regression analysis, particularly of qualitative factors such as labor productivity, capital-output ratio, production cost and profitability, is becoming increasingly widespread in the sector's technical and economic investigations. The first steps in this direction within the sector were made during the Ninth Five-Year Plan by the economic departments of INEUM [Institute of Electronic Control Machines, USSR Academy of Sciences] and TsNIITEI Priborostroyeniya [Central Instrument-Making Scientific Research Institute of Information and Technical and Economic Research] (Moscow). Good results have already been obtained by VNIPI OASU in development of multifactorial regression models of labor productivity. In the future, regression models are likely to constitute the basis for planning of the above-mentioned quality indicators and also for their connection with the accounting principles of operations management in the sector.

Comprehensive analysis of the activities of individual enterprises which are behind schedule in the fulfillment of the basis economic indicators is being conducted in the sector. This complex analysis is carried out according to three aspects of a special program: economic, organizational and technological. The economic analysis calls for the establishment of monthly average productivity for the last 2 to 3 years, and study of the structure of the labor force, worker qualifications, the labor intensity of the production program and the individual products for the period as a whole and for the individual types of work, the amount of commodity production and the size of the products list, and also the production costs. In organizational analysis, the presence of the Organizational Manual, the Regulations on Planning and Internal Operations, and the Regulations for Services and Allocation of Duties is checked. The technological analysis entails the identification of the enterprise's capacity, the compatibility of the existing equipment with the planned production program, the identification of bottlenecks and ways of eliminating them, estimation of the evenness of the enterprise's operation and of the coefficients of utilization of productive capacities and equipment, and also of accelerated mastery of planned capability and so on.

The analysis must lead to conclusions and specific recommendations for improvement of production efficiency. It should be noted that economic, organizational and technological analysis should be closely interrelated and should complement each other.

Improvement of sectorial planning during the Tenth Five-Year Plan requires development of a new normative base, since in comprehensive terms the problem of developing a normative base for the national economy has not been solved. At present, efforts to develop a system of interconnected norms are under way in the sector. All scientific research organizations which have economic subdivisions have been pressed into service in this effort. The development of a normative base will make it possible not only to improve the soundness of the plans, but also to set and accomplish completely new tasks in planning and management, and to expand sharply the area of application of economic and mathematical methods.

The system of interconnected sectorial norms takes in three management levels: the enterprise (PO or NPO), the subsector (VPO) and the ministry. There are two sets of norms for planning and management of the sector. The first encompasses the universally-known norms for expenditure and utilization of resources: material, labor, fixed capital and circulating capital. The other consists of norms which measure the basic relationships between the main approved plan indicators. It is these norms which must be the definitive reference in planning and management. The norms must be constructed for each planning period (for current, five-year plan and long-term planning and management), and must be strictly interrelated in terms of these and also in terms of the vertical and horizontal aspects of production (between various types of norms). Unfortunately, heretofore no methods for establishing such interrelationships have been developed, especially for the middle and upper levels of management. In our view, the interrelationships must be made by the use of traditional balance methods and also by employing new mathematical modeling techniques. To construct corresponding norms for the vertical direction, use may be made of statistical series, extrapolation methods and correlation analysis, and when constructing horizontal norms it is necessary to develop multilevel models which use production functions, multiple linear and nonlinear correlation methods and optimal planning techniques.

The development and operation of the system of sectorial norms proceeds on the basis of the existing systems of association and enterprise management. The project is to be constructed in several stages. Initially, norms of the first type will be developed. During this stage the norms of the second type will be developed by traditional methods. At the same time, methods of interconnecting the norms must be designated. Normative reference materials will be developed after performance of the first stage of the work in the sector. On the basis of these, banks of normative data will be developed during the second stage.

The comprehensive sectorial plan for technical and economic research calls for efforts to improve planned price determination in the sector. In methodological terms, it is proposed to determine during the Tenth Five-Year Plan the prices for all types of new instrument construction products, and to reflect in the prices of the instruments both their quality and the special characteristics of export price structure. No less important for price determination are the sizes of profitability norms in the prices of instrument building products, and the calculation of prices for specific products taking account of the capital intensiveness of their production.

Efforts to determine the capital intensiveness of products on the basis of information used in ASU-Pribor have begun in the sector. A "Method of Calculating Unit Capital Intensiveness" has been developed and is undergoing experimental testing. The performance of this work will make it possible, by the end of the Tenth Five-Year Plan, to establish the capital intensiveness of practically all products, and will make possible the calculation of their prices in terms of profitability and proportional capital intensiveness. This in turn will make it possible to resolve, to a certain degree, the problem of variations in efficiency between products, enterprises and subsectors, and to fix the principles of cost accounting.

The improvement of pricing is inseparably connected with the development of cost accounting in the national economy. During the Tenth Five-Year plan, it is planned to improve pricing in the sector through a deeper penetration of all cost accounting methods currently used in it to all levels of management: ministry, VPO, PO and NPO, enterprise and organization. For this purpose it is proposed to improve the complex of measures for the development of "methodologies for cost accounting within the enterprise," for the development and utilization of economic incentive funds for production associations and especially NPO's, for the classification of wage categories in force in production associations and NPO's, for the determination of the number of personnel in their management organs and the size of their wage funds, and for determination of interrelationships between VPO's, PO's and NPO's, and between the enterprises and organizations within them.

It is proposed to make broader use of the principles of cost accounting in the scientific research and design organizations of the sector as well. For this purpose, alterations in evaluation of the activities of these organizations, in the formation and utilization of their economic incentive funds, and in the principles of financing scientific research work of various types have been proposed.

Problems of management of the scientific and technical process occupy an independent position in the plan for the sector's technical and economic research during the Tenth Five-Year Plan. These include both problems of perspective and long-range forecasting of sectorial development and problems of management of scientific research.

During the Tenth Five-Year Plan, it is proposed to continue work on the perspective plan for the development of the sector over a 15-year period. At the same time, efforts to expand the planning horizon by establishing hypotheses for the development of the sector to the year 2000 will be made. This area of research is directly connected with efforts to determine the national economy's requirements for instruments. Perspective planning and long-range forecasting presuppose a simultaneous and comprehensive comparative analysis of the technical and economic indicators for the development of instrument making in the USSR and advanced foreign countries.

The problems of evaluating the economic effect of new projects and of assuring increased efficiency in the national economy through incorporation of new and more advanced automation equipment have been identified as the main problems for scientific research during the Tenth Five-Year Plan. No less significant for the solution of this problem is the shortening of the science-to-production cycle.

As was noted above, sectorial technical and economic research is the basis for improvement of sectorial management through ASU-Pribor. The plan for comprehensive sectorial technical and economic research has identified as the main tasks for the developers of ASU-Pribor during the Tenth Five-Year Plan the incorporation and further improvement of comprehensive automation of the system

for collection, storage and updating of norms required for the development of national economic plans (and the comprehensive ASN [automated norm system]) and the expansion of work on the technical and planning subsystem, in particular work on the technical and economic analysis block within this subsystem.

The most important task of the developers of ASU-Pribor during the Tenth Five-Year Plan is the development and incorporation of the sectorial planned price determination subsystem. The development of this subsystem will make possible more efficient organization of the library of reference price lists, initial development of price lists by computer in certain subsectors using methods of mathematical economics, and the solution of a number of other tasks. Equal significance is accorded to the comprehensive plans for technical and economic research and efforts to develop and improve enterprise and organization ASU's. During the Tenth Five-Year Plan, enterprise ASU's and cluster computer centers will become the main sources for initial information for ASU-Pribor and the point at which management responses are received from it in turn.

The comprehensive plan for technical and economic research in the sector during 1976-1980 will be implemented as follows: the leading organization in the sector will draw up plans relating to each problem and coordinate all work with the main subsectorial organizations. The latter will coordinate the work of the economic subdivisions within their subsectors.

The leading organizations' plans will specify the stages and substages of technical and economic research and their budgeted costs, taking into account expenditures by the organizations which are co-performers. Financing will be conducted through the centralized fund for scientific and technical development.

In conclusion, it should be noted that the development of the five-year plan for technical and economic research makes possible the concentration of the efforts of the available corps of economists on the solution of critical sectorial economic problems, the elimination of duplication in the work of individual organizations, and the abandonment of unnecessary and unproductive topics. Fulfillment of the plan will lead to a strengthening of the unity of the methodological bases of planning and accounting at all levels of sectorial management and a more profound utilization by the sector and the enterprises of automatic control systems which have been developed and are in operation. All of this will make it possible to improve the quality and efficiency of work in the sector as a whole.

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AUTOMATIC CONTROL SYSTEMS AT CHEMISTRY EXPOSITION

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 pp 55-57

[Article by Engineers G. N. Yegorov and Yu. A. Golant: "Automatic Control Systems at the Khimiya-77 Exposition (Soviet Section)"]

[Text] There was an extensive display of automatic control systems designed for use in the chemical, petrochemical and other industries at the special Khimiya-77 international exposition, which was held in Sokol'niki Park between 1 and 15 September 1977.

The Soviet section included eight exhibits, devoted to the role of computer technology in enterprise, production facility and industrial process control systems, as well as scientific and laboratory research.

Diplomas from the All-Union Palace of Industry and Trade were awarded to an automated process control system for bulk polymerization of vinyl chloride, an automated process control system for the production of ammonia with a capacity of 600 tons per day (ASU AM-600), a laboratory ASU (the Eksperiment) and a chemical plant ASU.

The process ASU for the bulk polymerization of vinyl chloride is designed for automatic control of this process and enables it to be conducted with optimum technical and economic indicators.

A full-scale model of the control system, based on the Hungarian Videoton 1010B computer and the PO/MP-8000 equipment and software complex was displayed at the exhibition.

This system performs the following functions: automatic startup and shutdown of vinyl chloride polymerization units; automatically bringing the process in the reaction vessels to a given state; stabilization of the process in the reaction vessels at the polymerization stage; optimal selection of process and schedule for the main process equipment for minimum consumption; automatic monitoring of the state of the process equipment and parameters.

The system makes use of the unified PO-8000 YeS [unified system] software to perform all the above functions. The PO-8000 includes the "Sintez" package, which carries out "programmed design" of the system and makes possible structural and parametric adjustment of the control system.

The system includes the MP-8000 process engineer's station, which performs:

display of the process parameters on recording and indicating instruments; automatic and manual control of 2-position actuating mechanisms; selection of control mode (direct digital control, automatic, manual); signaling of the state of the process parameters and the 2-position actuating mechanisms; alphanumeric display of the state of the process; automatic startup of process operation; memory storage of limiting values for process parameters; digital display of the values of process parameters stored in memory; and duplication of control computer operation by analog regulators.

The system provides automatic control of periodic operations, the bringing of the reaction vessels to their operating state, and also the possibility of testing and implementing, without any special programming knowledge, single- and multicascade regulation schemes and standard tasks of process control.

An operating model of an automated process control system for the production of ammonia, with a capacity of 600 tons a day, along with part of the monitor and control panel, was displayed. The system was designed to provide centralized operational control of a single process line for the production of ammonia; it performs: selection, processing and display of information for the attendant; calculation and analysis of the technical and economic indicators for the operation of sections and the shop as a whole; indication of state and protection of the equipment during disruption of the process; indication of above-normal gas readings in the facility; calculation and maintenance of optimum process parameter values in the gas synthesis section; and direct digital control of the main processes.

The system makes use of computer equipment based on the domestically produced M-6000 computer, logic units and local automation equipment.

Information is displayed for the attendants, either on the dispatcher's call or automatically, by a digital computer complex. The operational introduction of new data or alteration of data in memory is carried out on a keyboard at the data readout station.

The system provides for smooth automatic transition to the reserve system of local automation in case of failure of the control computer. The panel and the mnemocircuit systems are developed on a unified design basis in keeping with modern requirements of industrial esthetics, and make for convenience of operation and minimal burden for the attendants.

This process control system differs from earlier control systems for these complex processes by incorporating electrical equipment from the State Instrument System, a control computer operating in the direct digital control mode, and optimal control of production processes in terms of economic criteria and of the collection and processing of information, with a readout of the technical and economic indicators of the operation of the AM-600 and the shop as a whole.

The annual economic effect expected from the incorporation of a single system is 1.06 million rubles.

The reliability of system operation is determined primarily by the reliability of the M-6000 computer.

The Eksperiment automated data collection, analysis and storage system for scientific research and shop laboratories is designed to handle data from a complex of analytical equipment: gas and liquid chromatographs, microcalorimeters, infrared and ultraviolet spectrometers, the Dipol'-A dielectric constant meter and units controlling instrument operation.

A full-scale working model of the system, based on the Videoton 1010B computer (also displayed as part of the vinyl chloride process control system), a laboratory chromatograph and the Dipol'-A meter, was on display. The instruments were connected to the computer simultaneously and operated independently of each other. The system carries out the collection and initial processing of signals from the analytical control sensors, analysis of the data and printout of the processing results, storage and accumulation of experimental data, and control of analytical instruments of the periodic type.

The Eksperiment system makes it possible, without special knowledge of programming, to carry out various modes of processing and analysis of the data from different instruments, and also to perform standard tasks in control of periodic analytical equipment such as component dispensers, startup and shutdown of individual blocks and actuating mechanisms of instruments, program control and so on.

The system software includes the following programs and program subsystems: a real-time supervisor; the Kontrol' program for initial processing of signals from the analytical instruments and sensors; the Khrom subsystem for processing and analysis of data from the chromatographs and printout of the results; the Spektr subsystem for monitoring and analysis of information from the spectrometers and simultaneous recording of the information on disk; the Kalorimetr subsystem for analysis of information from microcalorimeters and printout of the result; the Upravleniye subsystem for control of periodic type analytical instruments; the interactive Sintez subsystem for input of data on specific instruments and the procedure for processing data from them; the Fon program package for determination of the quantitative characteristics of spectra recorded on disk; and the Katalog program package for identification of compounds by their Kovacs index and the formation and expansion of a catalog of indices.

The real-time supervisor effects the initial system startup and the processing of interrupt signals, establishes the priority for performance of the programs, controls the course of interrupt inquiry programs, determines the priority for performing the background [Fon] programs and calling them from the disk, calls programs from working memory and long-term storage at the operator's request, controls information exchange with peripherals, organizes files on disk and reads out information on them, protects the programs from temporary electrical failure and assures continued program operation after power is restored.

The operator interacts with the supervisor in the dialog mode.

The Kontrol' program accepts signals from analog sensors (256 per analog-digital converter, and a maximum of 1,024) with an interrogation frequency of 1-7 seconds, with exponential signal smoothing, and checks signal reliability in terms of level and rate of change. The sensor may have standard or special scaling.

The Khrom subsystem, operating in the real-time mode, determines the zero signal level and constantly tracks it during the analysis, determines the peak heights and the delay times for the components, computes the areas of the peaks, stores the signal, prints it out at predetermined intervals and calculates the areas of the peaks in the tail of the main component. After conclusion of the chromatographic analysis it operates in the background mode (internal standard, normalization or absolute calibration), prints out the results, and reprocesses the data for a given analysis if the user is not satisfied with the results.

The Spektr subsystem, operating in the real-time mode, smoothes the signal by the least-squares method, monitors data reliability, rejects non-informative intervals, and records the spectra from several instruments on disk simultaneously. After conclusion of the analysis it prints out on the laboratory terminal (or teletype) the coordinates of the spectra on disk, the coordinates of the experimental values (at the user's request) and the integrals of the absorption zones for the recorded spectra.

The Kalorimetr subsystem determines the specific heat, the heat of phase transition, and specific heat as a function of temperature; reprocesses the data according to an alternate scheme; and prints out the recorded spectrum (or experimental curve) and the results of processing of the data.

The Upravleniye subsystem consists of a control program and a set of subroutines which control discrete units (shutoff valves, electric motor starters and so on), ingredient feed, startup and shutdown of centrifugal pumps, and perform logical AND or OR operations on discrete input signals, compare analog signals with constants and with each other, and carry out program regulation over time. This inventory of fundamental operations also makes it possible to perform standard tasks in the control of periodic analytical instruments such as dispensing of ingredients and startup of instrument operations, regulation of a process according to a specific program, switching of gas flows in process circuits and so on.

The Sintez subsystem provides logical monitoring of the responses of a user engaged in dialog interaction with the system to questions presented by the system. The subsystem consists of a control program and an inventory of 115 procedures which accept and process, in the dialog mode, signals from analog and digital sensors, provide operational processing and analysis of experimental data and so on.

The Fon program package makes it possible to determine the extreme values of any spectrum recorded on disk, to determine the area of the absorption zone in given intervals, to calculate the coefficient of correlation between two spectra and so on.

The Katalog program package is designed to identify unknown compounds and determine their quantitative content in multicomponent mixtures.

Experience has shown that use of the Eksperiment system makes it possible to decrease the time required for analyses by a factor of 20. The universal software of the Eksperiment system was developed for use with the Hungarian Videoton YeS-1010 computer.

A full-scale working model of an automated system for control of the production activity of a chemical enterprise, based on the YeS-1020 third-generation computer, was also displayed. Thus ASUP is based on a unified set of norms and performs the following tasks: technical and economic planning, including calculation of the optimal variant of an annual production program, calculation of planned indicators (energy resource requirements, production cost of commodity output and so on, a total of 17 tasks); management of marketing and sales, including accounting of product output and of fulfillment of the shipment plan, forecasting of sales plan fulfillment and so on (9 tasks); material and technical support, including calculation of material resource requirements for the production plan, operational calculation of movement of materials and so on (9 tasks); operational management of basic production, including calculation of quarterly and monthly output plans and so on; and comprehensive bookkeeping.

The programs are based on COBOL, PL-1 and RPG. The ASUP software includes standard applied linear programming packages: LPS-360 (IBM) for calculation of the optimal variant of the annual production plan, and an input-output information generator (developed by TsNIITU, Minsk) for control of data input into the computer.

The main advantage of this system is that, in the opinion of Soviet and foreign specialists, it is capable of becoming a standard prototype system for medium-sized chemical enterprises.

The exhibits also included a full-scale model of the SM-1 control complex of a system of minicomputers; a full-scale model of an automatic control unit for moving-picture material production processes; and an electrified model of an automated process control system for production of simple polyesters and olefins (based on the 1010B computer).

The displays evoked considerable interest from Soviet and foreign specialists, who noted the up-to-date ASU construction ideology and the unification of the equipment and software used.

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

SOFTWARE AND INFORMATION SUPPORT FOR AUTOMATED PROCESS CONTROL SYSTEMS

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 pp 60-61

[Article by Kandidat of Technical Sciences V. N. Okunenkov and Engineer Yu. A. Golant]

[Text] An all-union scientific and technical conference dealing with the above theme, organized by the central and Ukrainian scientific and technical societies of the instrument-making industry, the board of the Chernovitskaya Oblast Scientific and Technical Organization of the Instrument-Making Industry imeni Academician S. I. Vavilov, and the Chernovtsy Branch of the Kiev Institute of Automatic Control imeni the 25th CPSU Congress, was held on 11-14 October 1977 in Chernovtsy.

Some 318 representatives of 182 organizations in 72 cities took part in the work of the conference.

The conference was divided into four sections:

1. Methods of identification, optimization and modeling in process ASU's [automatic control systems];
2. Algorithmic and programming modules and applied program packages for process ASU's;
3. Process ASU software for continuous-discrete and discrete production types;
4. Process ASU software for continuous production types.

Half of the conference participants worked in the second section.

Some 125 reports (out of 450 received), dealing with problems of development, incorporation and operation of special software and information support for process ASU's in various branches of industry, were presented at the conference.

It was noted in the reports that in the previous and current five-year plans a significant number of process ASU's were developed and incorporated in ferrous and nonferrous metallurgy and the chemical, power engineering, machine building and other sectors. However, development time and the economic effect realized from introducing the various process ASU's has frequently been disappointing. This is because the development of the structural and algorithmic part of the process ASU frequently takes the form of special-design software which, on one hand, is not conducive to changing the tasks of the system in question, and on the other does not favor the duplication of the control system in similar plants.

Sectorial libraries of algorithmic and program modules for process ASU's are currently being assembled in the main industrial sectors. The Kiev ASU Planning and Design Bureau has been designated the leading organization in the Ministry of Instrument Making for the development of the library of algorithms and programs.

The program for the development of sectorial libraries calls for: development and improvement of mathematical methods of performing process ASU tasks; development of sectorial libraries of algorithmic and program modules for performance of standard process ASU tasks; preparation for periodic issuance of collections of algorithmic and program modules; and development of a training system for programmers and personnel engaged in developing algorithms.

The transmittal of algorithmic and software modules to the sectorial library is to be proposed only after industrial testing.

The conference considered it expedient to ask the Ministry of Instrument Making to organize the training of specialists in M-6000 and M-7000 computer complex software for the western parts of the country, under the Chernovtsy Branch of the Kiev Institute of Automatic Control imeni the 25th CPSU Congress.

An all-union scientific and technical conference on the development of process ASU software and prospects for its development is planned for 1979.

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

NEW BOOKS ON COMPUTER ENGINEERING DESCRIBED

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 6, 1978 p 61

[Text] S. V. Dmitriyev. Matrichnyye struktury EVM i upravlyayushchikh sistem [Matrix Structures of Computers and Control Systems]. Moscow, Nauka, 1977. 119 pp. (Institute of Information Transmission Problems, USSR Academy of Sciences). 3,300 copies. 80 kopeks.

Problems of magnetically controlled memory elements and direct-access storage units. Methods of improving their characteristics and increasing speed of operation by using multicoordinate control and bias currents.

For scientists and engineers in the computer engineering and switching fields.

M. A. Rozenblat, ed. Domennyye i magnitoopticheskiye zapominayushchiye ustroystva. Sbornik statey [Papers on Domain and Magneto-optical Memory Units]. Moscow, Nauka, 1977. 262 pp. (Institute of Control Problems, USSR Academy of Sciences). 1,500 copies. 1 ruble 80 kopeks.

Physics of cylindrical magnetic domains (CMD). Theory and principles of construction of components of CMD units and materials for them. Description and characteristics of memory and logic domains and magneto-optical devices.

For specialists in computer engineering.

I. Y. Yefimov; Yu. I. Gorbunov; and I. Ya. Kozyr'. Mikroelektronika. Fizicheskiye i tekhnologicheskiye osnovy nadezhnosti [Microelectronics: Physical and Engineering Foundations of Reliability]. Textbook for colleges. Moscow, Vysshaya Shkola, 1977. 416 pp. 25,000 copies. 1 ruble 30 kopeks.

Physical phenomena and processes occurring in semiconductor and film structures, physical principles of operation of monolithic integrated circuits based on them. Design and manufacturing fundamentals, materials and components for manufacture of integrated circuits. Technological foundations of microelectronics and industrial processes for manufacture, control and testing of integrated circuits, questions of quality and reliability.

Ye. Ye. Zav'yalov; V. I. Zuyev; and A. A. Rybakov. Raschet i proyektirovaniye magnitnykh blokov OZU [Calculation and Planning of Magnetic Direct-Access Memory Blocks]. Moscow, Mashinostroyeniye, 1977. 104 pp. (Computer engineering). 8,000 copies. 27 kopeks.

Calculation and planning of direct-access memory units using ferrite cores and perforated ferrite plates. Theoretical questions of digital modeling of switching processes in data storage cells. A new model for the ferrite memory element, describing the most characteristic modes of its operation. Method of identifying model parameters. Modeling error and evaluation of adequacy of the model.

For engineering and technical personnel in the computer engineering field.

V. N. Roginskiy, ed. Informatsiya i informatsionnyye seti. Sbornik statey [Papers on Information and Information Networks]. Moscow, Nauka, 1977. 197 pp. (Institute of Information Transmission Problems, USSR Academy of Sciences). 3,000 copies. 1 ruble 20 kopeks.

Methodological problems of information theory, the study of transmission and recovery of telegraph and telephone information and the problems of information systems development. Economic questions of development of these systems. Problems of construction and operation of data transmission networks, effectiveness indicators, methods of calculating elements or links. Investigation of questions of reliability and ways of incorporating integrated digital networks.

For specialists in information theory and automatic control systems.

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OPTIMIZATION PRINCIPLES AND RESULTS OF EXPERIMENTAL TESTING OF A PACKAGE
OF SUBROUTINES ORIENTED TOWARD THE PREPARATION OF DIALOG AND TRAINING PROGRAMS

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan/Feb 78
pp 41-47 submitted 12 October 1976, revised 30 March 1977

[Article by V. N. Belov, and A. M. Dovgyallo]

[Text] Introduction

The idea of training the computer users by making use of the computers themselves is becoming more and more widespread. The Soviet computers are being intensively outfitted with various terminals (displays, teletypes, typewriters), and this is making it possible to make broad use of the dialog mode of operation. Our country has experience in the application of computers for training users.

This is the origin of the PEDAGOG system for teaching COBOL [1], the DIPROFOR decision-training system for programming algorithms for the solution of defined problems in FORTRAN [2], the algorithm designer DISAOD [3], and so on. The experience in the operation of these systems has demonstrated that they can be effectively used for training. The problem of the creation of means of automating the production of these training programs is a highly important, urgent problem. Out of the foreign means for this purpose, it is necessary to mention the Coursewriter system of the IBM Corporation [4], the Tutor system of the CDC Company [5], the PILOT system of Hewlett-Packard [6]. The training programs are being written with the help of special languages which are quite simple and easily mastered. The author of the training program has a large range of conveniences and capabilities at his disposal. Seated at the terminal, he can write the training programs, check them out, test them, correct them and enter them in the archive. It must be noted that all of these conveniences arise to a significant degree from the good computer hardware and common software on which these systems are implemented.

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SUBROUTINE KADRI (NEXT)
DIMENSION ANS(15),PAT(10)
CALL TYPE (CH5NNAME CAPITAL
OF THE PEOPLES REPUBLIC OF ANGOLA)
LOOP=1
CALL LET(PAT. 7NLUANDA)
33 CALL TAKE(ANS)
IF(LINE(ANS))14,11,11
11 IF(MATCH(PAT,ANS))3,3,12
3 CALL TYPE(27NBAD. YOU DO NOT
READ THE NEWSPAPER.)
LOOP=LOOP-1
IF(LOOP)22,33,22
22 NEXT=5
RETURN
14 CALL TYPE (22NBEGINS AT L)
GO TO 33
12 CALL TYPE(CH2NI AM GLAD THAT YOU FOLLOW
EVENTS IN THE WORLD.)
NEXT=6
RETURN
END

```

Figure 1.

The Cybernetics Institute of the Ukrainian SSR Academy of Sciences, jointly with the interuniversity computer center of the Riga Polytechnical Institute has made an effort to develop means of constructing dialog and training programs based on a high-level programming language. The widely used FORTRAN language was selected as the base language. In our system which is called KODIAL (KONstruction of DIALogs), no new language is defined. All of the required functions are executed using subroutines; therefore KODIAL can be considered as an expansion of FORTRAN for writing dialog and training programs (the idea itself of expanding the language by subroutines is not new; for example, the SLIP list processing system based on FORTRAN is available [7]).

This approach to the creation of a specialized programming system has defined advantages. First, an author who has mastered FORTRAN need not study a new, even very simple language to write the training programs. Secondly, the specialized languages are used primarily to write relatively simple and small training programs used, as a rule, within the framework of a lesson and not having "long life." In order to write sufficiently complex and unique programs (like the above-mentioned DIPROFOR and DISKAOD), the maintenance of these programs under the conditions of a variable hardware and software base will become a primary problem. FORTRAN ensures "long life" for such systems. In addition, the use of FORTRAN to write the subroutines entering into the system itself designed for writing the training programs, significantly lowers the labor consumption of the creation of the system, and it improves its documentability.

This approach is characteristic of the syntactic methods of analysis which have recently become widespread as a result of the intense development of the theory of formal grammars. The syntactically controlled analyzer can also be considered as a module with two inputs and one output. The first input is a human message which must be analyzed, and the second, a grammar, by the rules of which the message is analyzed. The output is equal to 1 if the analysis is successful and 0 otherwise.

As the second input it is expedient to use a theoretically well-developed class of context-free grammars.

As is known, the context-free (CF) grammar is a quadruplet (V_T, V_N, P, S) , where V_T is a finite set (alphabet) of terminal symbols, from which the language chains are constructed; V_N is the final set of nonterminal symbols; P is the finite of rules of the type $A \rightarrow \phi$, where $A \in V_N$; $\phi \in \{V_N \cup V_T\}$; S is the axiom of the grammar.

Applying the rules from the set P , it is possible to derive chains made up only of terminal symbols from the axiom.

As an example let us consider the following grammar:

```

TERMI = (VT, VN, P, S)
VT = { ( ), I F X }
VN = { <term> <fun> <pe> <spte> }
P: 1) <term> → <fun> (<spte>)
    2) <term> → <fun>
    3) <term> → <pe>
    4) <spte> → <term>
    5) <spte> → <spte>, <term>
    6) <fun> → <fun> 1
    7) <fun> → F
    8) <pe> → <pe> 1
    9) <pe> → X
S = <term>

```

This grammar gives the rules for the construction of the terms in predicate calculus. The identifiers for the functional symbols and the object variables are constructed from the letters F and X , respectively, in which it is possible to affix as many units as one might like on the right.

The derivation of a chain $(F(F1, X))$ in the TERMI grammar appears as follows:

```

<term> → <fun> (<spte>) → <fun> (<spte>,
<term>) → <fun> (<spte>, <pe>) → <fun>
(<spte>, X) → <fun> (<term>, X) → <fun>
(<fun>, X) → <fun> (<fun>
I, X) → <fun> (F1, X) → F (F1, X)

```

This derivation can be abbreviated by indicating the sequence of numbers of the grammar rules: 1, 5, 3, 9, 4, 2, 6, 7, 7.

The analysis is the inverse process: the chain is given, and it must be reduced to an axiom, applying the rules. If this can be done, then the chain belongs to the language generated by the given grammar.

The analysis algorithm which operates with simple precedence grammars [10] (they form the subclass of CF grammars) and affixed for operation in the dialog mode has been developed for the KODIAL-2 system. The mechanism of convolution of the chains coincides with that described in [10], but the distinguishing feature of our algorithm is the fact that the axiom is given as an input parameter, and it can be any nonterminal symbol of the grammar [11]. In one set of rules this makes it possible to operate actually with K grammars where K is the number of nonterminal symbols.

```
BEGIN TO INPUT TEXT FOR OUTPUT TO THE TRAINEE.
=HELP//
TEXT IS INPUT IN PORTIONS OF NO MORE THAN 50 SYMBOLS EACH
IF NO TEXT: ANSWER END.
=NAME THE CAPITAL OF THE PEOPLES REPUBLIC OF ANGOLA.//
=END//
REPORT THE NUMBER OF ATTEMPTS TO ANSWER GIVEN TO THE TRAINEE.
=1//
INPUT THE STANDARD.
=LUANDA//
MATCH--ANALYSIS OF ENTRY OF A KEY WORD INTO THE ANSWER
IDENT--ANALYSIS FOR EXACT COMPARISON WITH THE STANDARD
NAME THE FUNCTION REQUIRED BY YOU
=MATCH//
BRING IN THE INCORRECT ANSWER BY THE TRAINEE MESSAGE.
=BAD. YOU DO NOT READ THE NEWSPAPERS.//
=END//
```

Figure 2.

The algorithm was executed as an expansion of KODIAL-1 in the form of a FORTRAN subroutine function with three parameters:

```
SYNT1 (STR, GRAMM, AXIOM),
```

where STR is the line for analysis; GRAMM is a variable with the name of the grammar, by the rules of which the line must be analyzed; AXIOM is the variable with the name of the axiom.

KODIAL-1. The first version of KODIAL was implemented on the Minsk-32 computer in 1974 [8]. KODIAL-1 is made up of the subroutines of the FUNCTION and SUBROUTINE type ensuring the operation of symbolic rows (removal, shift, concatenation, and so on), the organization of message exchange, the analysis of the responses of the trainees with respect to the standards and key words. The basic goal when creating these subroutines consisted in writing everything possible in FORTRAN. The KODIAL-1 subroutines form a hierarchical structure, on the lowest level of which there are two basic subroutines for reading a symbol in a word and writing a symbol in a word written in low-level language (YASK for the Minsk-32 computer).

The fragment of the training program in KODIAL-1 (Figure 1) is an ordinary FORTRAN program including reference to the KODIAL procedures in itself. The training course can be made up of a set of such fragments which are translated independently of each other, and then are either gathered together by the SBORSHCHIK [assembler] systems program or called by the lead program as necessary into the ready-access memory for execution.

The further development which led to the creation of a second version of KODIAL (KODIAL-2) took place in two directions. The first was devoted to the expansion of the possibilities of KODIAL, namely, inclusion of a syntactically controllable analyzer in the system and development of means providing for dialog solution of problems. The second area dealt with system problems and was devoted to ensuring normal operation at the terminals in the multiprogramming mode.

KODIAL-2. Message Analysis. The analysis of human messages in KODIAL-1 was realized by the procedures of checking for comparison of the answer with the standard and testing for the entry of the key word into the response. The analysis program by standards can be considered as a module having two inputs and one output. The first input is the human response and the second, the standard. Thus, the program gives a general analysis algorithm (a very simple one) which operates on a set of standards. However, there are cases where the analysis method by standards is unacceptable.

Let us assume that we wish to achieve machine recognition of lines which are all-possible terms and predicate calculus [9], for example $F(F(x))$, and so on. It is possible to form very many such lines; therefore in practice we cannot give the standards. In this case it is possible to talk about the structure of these lines given by syntactic rules. We talk about syntax also when we are studying, for example, programming languages. When using the terms, it is possible to write a relatively simple program which will analyze the lines for correctness. The rules will be contained in implicit form in the program itself. However, this program will recognize only the terms, and the generality which the algorithm for analysis by standard had (the standards change, but the program does not change) will be eliminated. This generality can be ensured by making syntax rules the input information for the recognition program.

The SINT1 function assumes a value of 1 if the analysis is successful and 0 otherwise. In addition, through COMMON it is possible to obtain a sequence of numbers used in the process of analyzing the rules and also the numbers of erroneous symbol in the line in the case of unsuccessful analysis.

In the actual parameters of the SINT1 the names of the grammars and the axioms are given by the text constants. SINT1 can operate in combination with the other KODIAL subroutines.

Here is how it is possible to check the correctness of the input FORTRAN identifier:

```

      . . . . .
      CALL TAKE (STR)
      IF (SYNT1 (STR, 5HGRAMM, 5HIDENT)) 21, 22, 21
21  IF (LONG (STR) -- 6) 32, 32, 31
      . . . . .
22  CALL TYPE (18NSYNTAX INCORRECT 4)
      . . . . .
31  CALL TYPE (16NTOO LONG 4)
      . . . . .
32  CALL TYPE (6NCORRECT 4)

```

The KODIAL function LONG measures the line length. GRAMM is the name of the grammar including the rules defining IDENT identifier in FORTRAN. It must be emphasized that a "higher" goal of this grammar can be a more complex construction than an identifier. The assignment of the grammars is described below.

SOAVTOR [COAUTHOR]. The COAUTHOR service complex includes the programs TALK2, GRAMM, ANALI written in KODIAL and operating in the dialog mode.

The programmer that has mastered FORTRAN can write dialog and training programs without special effort. The people who do not know FORTRAN can use the TALK2 program which helps to set up the training fragments and if the user wishes, it prints out the fragment and enters it in the archive. An example of the operation of TALK2 is presented in Figure 2.

The GRAMM and ANALI programs provide for the formation of grammars which the SYNT1 function uses as one of the input parameters. One of the weightiest arguments in favor of the precedence grammars that we have selected is the fact that the analysis algorithm for them is simple and effective. However, when giving these grammars, it is necessary to construct a matrix or precedence functions which is a tedious process. Nevertheless, the advantage of their use is unquestioned, for the advantage of an effective analysis algorithm will manifest itself many times (on each reference to SYNT1). All of this will be valid under the condition where the process of construction of the precedence grammars is automated. The GRAMM program is used for this purpose. It provides for input of the initial CF grammar in the generally

accepted form either from the terminal or from the punch card input device, and it forms a simple precedence grammar. The conditions accumulated on the latter (the absence of conflicts of relations) are not always satisfied for arbitrary CF grammars. When detecting a conflict GRAMM outputs a message to the terminal, for example, the following type:

FIRST TYPE CONFLICT NR
3RD RULE

and it makes an effort to eliminate it by conversion of the initial CF grammar to the simple precedence grammar equivalent to it by the algorithm of [12]. The application of this algorithm causes the addition of new nonterminal symbols and rules to the initial grammar, and it always eliminates the conflicts of the precedence relations, but in this case, rules can appear with identical right-hand sides, which is unacceptable. From the theory of formal grammars it is known that no general conversion algorithm exists which guarantees that rules with identical right-hand sides will not appear in the resultant grammar. If the conversion has been successful, the message CONFLICT ELIMINATED is output; otherwise the number of the rule having an identical right-hand side with the newly formed one is output, and the user must change the grammar himself by using information about the conflict.

After the creation and recording of the grammar in the archive the user may wish to check whether he has actually obtained what he wanted. In this case he calls the ANALI program by means of which it is possible to check out any grammar from the archive, introducing various messages for analysis of it. As an axiom it is possible to give any nonterminal symbol of the checked grammar. Thus, the ANALI program is its own type of "test unit" for the created grammars.

In Figure 3 an example is presented of the creation and testing of the term I grammar defining the terms of the predicate calculus. On formation of a precedence grammar a second type conflict was detected which was eliminated without human intervention.

Organization of the Operation of the KODIAL System on the Minsk-32 Computer

It is possible to work with KODIAL in both the package and dialog modes. The former is used during translation, assembly and writing of KODIAL programs in the user's archive. In the analog mode the finished KODIAL programs and the COAUTHOR programs are executed in the dialog mode. The software available for the Minsk-32 computer makes it possible to realize the following versions of the multiprogramming mode:

Four analog assignments;

Three dialog assignments and one package;

Two analog assignments and one package;

One dialog assignment and one package.

Teletypes connected to the computer through the Minsk-1560 are used as the terminals. The selection of the version is determined by the ready-access memory reserve and the presence of terminals. At the interuniversity computer center of Riga Polytechnical Institute, for example, the third version has been implemented.

The dialog assignment begins with calling the ZHUCHOK [BEETLE] monitor program (the name of the monitor reflects the level of its intellect). This program which is loaded into the free operating level of the computer permits the required programs to be called from the terminal, it troubleshoots and organizes the communications between the user and the computer operator. The monitor "understands" only three directives:

```
/EXEC-XXXXX--load and execute program
XXXXX
/OPE-text--sending of instructions to the operator
/END--end of assignment
```

These directives must be entered after the following monitor messages:

```
BEETLE IS WAITING
BEETLE IS UNSATISFIED
BEETLE IS SORRY
BEETLE IS UNSATISFIED, if the user has entered something different
from the three above-indicated directives
BEETLE IS SORRY if a malfunction has occurred.
```

After execution of the directive /EXEC-XXXXX the XXXXX program controls the dialog.

The process of the solution of any of the problems on a computer includes data input and output. FORTRAN has powerful input-output means: the operators READ, WRITE, FORMAT. Unfortunately, they are inapplicable for working with terminals. The subroutine TYPEF has been developed and included in KODIAL as their equivalent. This subroutine provides for both input and output of information and has parameters giving lists and formats similar to FORTRAN. The reference to TYPEF has the following form:

```
CALL TYPEF (K, A, B, C, D, F),
```

where A, B, C, D is the input-output list made up of identifiers of variables and files. If there are less than four of them, then the symbol \diamond is inserted after the last one. It is the end of list symbol; K is the input or output symbol (K=-0 for input, K=0 for output); F is format (on input equal to 0).

Example 1. Input of the file C of real numbers from the terminal

```
DIMENSION C (15)
.....
CALL TYPEF (-0, C, 1H\diamond, 0, 0, 0)
```

```

GRAM. TERM1
INTRODUCE TERMINALS
=( ), 1 F X //
INTRODUCE NONTERMINALS
=TERM FUN PE SPTE )//
ENTER RULES
=TERM FUN ( SPTE L''
=TERM FUN//
=TERM PE//
=SPTE TERM//
=SPTE SPTE, TERM//
=FUN FUN 1//
=FUN F//
-PE PE 1//
=PE X//
=-----//
SECOND TYPE CONFLICT ( SPTE 1ST RULE
ELIMINATED.
ENTER TERM 1 GRAMMAR IN THE ARCHIVE?
=YES//
...
INTRODUCE TERM
=F(F,X11)//
AS CORRECT
=ANALYSIS//
= 7 7 6 2 4 9 8 8 3 5 1
=F(F1(X,F11(X1,F111)))//
CORRECT

```

Figure 3.

Example 2. Input of the integer 1 and the file C of real numbers:

```

DIMENSION C (15)
.....
CALL TYPEF (0, 1, C, 1H, 0, 12H (13/5 (10.3)))

```

In contrast to the display, the teletype does not have means of autonomous editing of the information; therefore it was necessary to invest the input subroutine with the possibility of correcting incorrect information, failure from the portion, failure from the K preceding symbols. The information required by the input list can be input in portions. On input, the numbers are separated from each other by gaps. The real numbers differ from the integers by the presence of points.

Results of Testing KODIAL-2. As a result of the experimental operation, it was established that various categories of users can use the KODIAL-2 system.

A teacher at the mechanics department of the Riga Polytechnical Institute wrote a dialog program using KODIAL on the basis of a FORTRAN course design program written by him in five passes on the computer.

A teacher in the automation department of Riga Polytechnical Institute not familiar with FORTRAN but programming in ALGOL was able to write a simple program for teaching the cycle concept in ALGOL after three sessions working with the TALK2 program. The new program became operative after four runs on the computer.

A systems programmer for the interuniversity computer center of Riga Polytechnical Institute, who was writing a dialog program for the solution of systems of differential equations, had to create a compiler for the generation of the instructions for calculating the right-hand sides of differential equations. The syntax of the formulas input from the terminal and giving the right-hand sides was determined by the grammar containing 44 symbols and 45 rules. After three runs on the computer, the required grammar was obtained, and the syntactic analysis problem was solved. A similar program in YASK was written in 18 to 20 passes on the computer.

Conclusion

The experimental operation of KODIAL has also confirmed the correctness of the initial concepts when creating a system. The programming of a large part of the system in FORTRAN significantly reduced the labor involved in writing it, and it ensured good documentability of the programs. In addition, the work on conversion of the system to the integrated computer system is simplified.

When working with KODIAL, bottlenecks were detected in the system. First, as a result of deep embedding of the KODIAL subroutines the assembly of the fragments took place slowly. Secondly, some frequently used subroutines written in FORTRAN operated "slowly." These critical subroutines were rewritten in YASK, and the bottlenecks were eliminated. In KODIAL-2 the proportion of KODIAL subroutines is about 70 percent.

Experience confirms the correctness of the following method of creating a new package of applied programs:

The system should be programmed in a high-level language insofar as possible;

Find all the "breaks" in the operating process;

Mend these "breaks" using the assembler type language.

Basing KODIAL on such a powerful programming language as FORTRAN made it possible to achieve another important advantage. The developed means will help in the development of dialog and training programs, using the enormous reserves of their FORTRAN "storehouse."

The inclusion of a syntactically controlled analyzer in KODIAL-2 invests the system with qualitatively new properties which are absent in the presently existing systems for similar purposes. The approach consisting in the creation of general algorithms using information about the structure of the objects given from the outside is highly prospective. It is possible to go farther in this direction, considering the formal systems of a broader class than a grammar. In particular, the logic of first order predicates is of interest. Implementing the mechanism of proof in this formal system, it is possible to imbue the training programs with deductive characteristics. Here the syntactically controlled analyzer will serve for recognition of correctly constructed formulas of the formal system.

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ASPROM AUTOMATED MICROPROGRAMMING SYSTEM: USER'S POINT OF VIEW

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan/Feb 78
pp 14-17 submitted 7 Jul 77

[Article by S. S. Zabara and A. D. Mil'ner]

[Text] The ASPROM system is designed for automatic preparation of microprograms in the technical design phase of digital devices with microprogram control. The system is executed on the M4030 computer, and a detailed description of the various aspects of it appears in references [1 to 4]. An effort is made in this article to investigate ASPROM from the point of view of the microprogrammer-user.

Functional Capabilities

The ASPROM system provides for the execution of the following basic functions:

- a) Storage of the initial symbolic programs written by the developer in the machine-oriented MIKROKOD language [3] in the computer memory;
- b) Analysis (syntactic and semantic control, simulation) of the microprograms in order to test their correctness;
- c) Conversion (translation) of the symbolic microprograms to their code equivalents with the possibility of automatic combination of independently compiled modules, automatic allocation of the microinstructions and determination of the control bits;
- d) Formation of the process representation of the microprograms, that is, the representations ensuring direct preparation of the control memory;
- e) The output of the working document of a reference or diagnostic nature depicting the current and final results of microprogramming in the system;
- f) Output of the set of operating and design documents to the controlling memory modules;

g) Obtaining the carriers (magnetic tapes, punch tapes, punch cards) for automation of the preparation of the controlling memory and monitoring of it;

h) Correction of the initial symbolic microprograms and the output documents.

The system is universal in the sense that it provides flexible adjustment to a broad class of microprogram bases characteristic of the microprogram processors of the medium-output computers, minicomputers and microcomputers and also the controllers of the satellite units. It is proposed that the controlling memory can be executed on the basis of arbitrary physical and process principles.

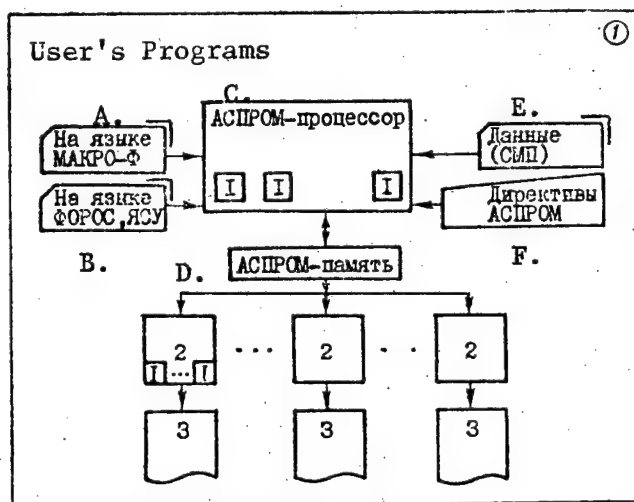
Model of the System

The microprogrammer considers the system (Figure 1) as made up of the following components:

The ASPROM processor;

The ASPROM memory;

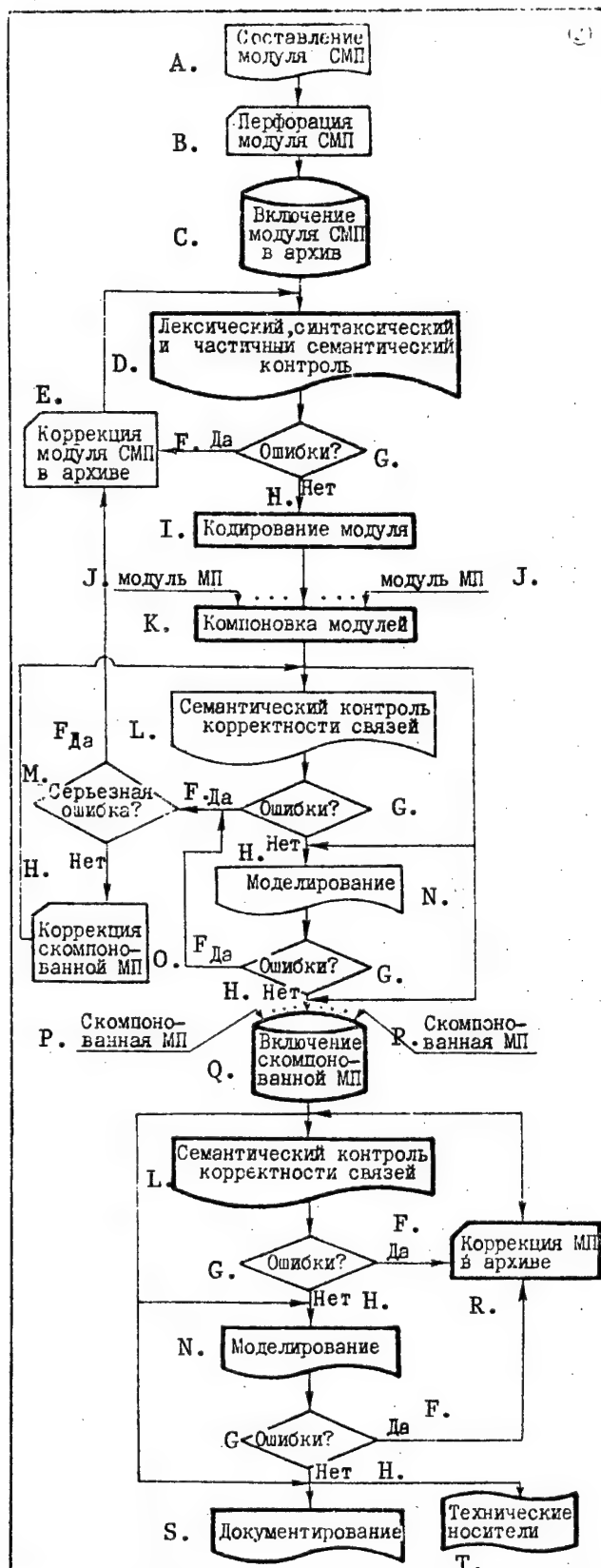
The set of postprocessors.



Model of the System: 1--Replaceable internal module; 2--Postprocessor; 3--Document.

Key:

- A. In MAKRO-F language;
- B. In FOROS language, YaSU [decision table language];
- C. ASPROM processor;
- D. ASPROM memory;
- E. Data (SMP);
- F. ASPROM directives.



Flow Chart of the Operation of ASPROM in the design stage: SMP--symbolic microprograms; MP--micro-program.

- Key:
- A. Writing the SMP module;
 - B. Punching the SMP module;
 - C. Inclusion of the SMP module in the archive;
 - D. Lexical, syntactic and partial semantic control;
 - E. Correction of the SMP module in the archive;
 - F. Yes;
 - G. Errors?
 - H. No
 - I. Coding of the module;
 - J. MP module;
 - K. Composition of the modules;
 - L. Semantic control of correctness of relations;
 - M. Serious error?
 - N. Simulation;
 - O. Correction of the composed MP;
 - P. Composed MP;
 - Q. Inclusion of the composed MP;
 - R. Correction of the MP in the archive;
 - S. Documentation;
 - T. Technical carriers.

The specialized postprocessors usually are developed for solving a specific problem, in particular, to obtain a document or carrier of specific content and (or) format (for example, a magnetic tape for automatic monitoring of the information in the PZU).

Some Restrictions

The following restrictions are imposed on the class of microprogram bases, the processing of which is possible in the ASPROM system.

1. There are no more than 16 formats in one microprogram base.
2. There is no more than one microinstruction in one cell of the control memory.
3. The length of the microinstruction (the controlling memory cell) is no more than 96 bits.
4. There are no more than 2^{16} cells in the controlling memory.
5. The length of the zone for including the microinstruction elements (except the constants and address of the next microinstruction) is no more than eight bits; for the constant and address there are no more than 16 bits. The zone can include up to 4 nonreplaceable fields.
6. There is a maximum of four logical conditions in a microinstruction. One logical condition can determine any of the four low-order bits of the address of the next microinstruction. There are no restrictions on the indirect branching.
7. The residual control determines no more than three versions of the decoding of the microinstructions. For example, the channel and central processor microprograms can be located in the same controlling memory.

Operating Procedure in the System

The preparation of microprograms in ASPROM is made up of the following steps:

1. Adjustment Stage. The system is oriented toward the specific microprogram base. In the majority of cases the adjustment is limited to writing and checking out user programs in MAKRO-F, YaSU and FOROS languages and specialized nonprocedural type languages. In cases where it is necessary to replace the inside modules of the system processors or develop a new postprocessor, a programmer is called on who is familiar with the structure of the data in the ASPROM memory and the system coordination.
2. Design Stage. The microprograms are developed and the technical documentation for the controlling memory and the process carriers is produced. The generalized schematic of the organization of operations in ASPROM in

The ASPROM processor realizes the functions of translation and analysis of the microprograms, and it controls the remaining components of the system.

The translation is made by interpretation of the user program (FORMULAR) written in the MAKRO-F nonprocedural (parametric) metalanguage [3]. This program discovers the lexical and syntactic errors in the initial microprograms and also the semantic errors connected with forbidden combinations of microoperations and logical conditions in the microinstructions (for example, writing different data simultaneously in the register).

The discovery of the more complex semantic errors (for example, forbidden combinations of microoperations in the chain of successively performed microinstructions) is accomplished by the ASPROM processor by interpretation of another user's program. This program is written in the decision table language (YaSU language).

The microprograms are simulated by a user program written in the procedural register transfer language FOROS [5].

The initial symbolic microprograms written in MIKROKOD are considered as input data for all of the user programs.

The orientation of the ASPROM processor toward the required subclass of microprogram bases is realized by replacing the processor modules.

The intermediate and final results of the operation of the ASPROM processor controlled by the user programs and the ASPROM directives are depicted in the ASPROM memory. These data can be visually displayed (put out as documents) and (or) converted for direct participation in the production process using the expandable set of postprocessors. Each such postprocessor performs a specific function and can be classified in one of three groups: universal postprocessor, broad-application postprocessor, specialized postprocessor.

The universal postprocessor operates under the control of the user's program written in MAKRO-F. First of all, this group of postprocessors includes the system components responsible for output of the operating documents [2].

The broad-application postprocessor is used for a subclass of microprogram bases and is controlled by the user's program written in a specialized nonprocedural type metalanguage. The processor for producing the "punch tables" [2] PZU of the transformer type is a classical example of a postprocessor in this group. Just as the basic processor, the given postprocessor contains replaceable modules. For example, one of the modules is responsible for obtaining the process representation of the microinstruction directly determining the production process of punching it (for example, the list of punched cores in the order of punching them).

this phase is presented in Figure 2. Each block in this flow chart outlined in boldface lines reflects the procedure performed by the system automatically. This procedure is initiated by the user with the help of the corresponding ASPROM directive given from the system console.

3. Tracking Stage. This stage includes two basic operations:

Entering changes in the ASPROM memory;

Re-output of the documents or individual lists of documents which are affected by the changes.

The microprograms are corrected by modules. The correction module is written in the MIKROKOD microprogramming language once independently of which documents are corrected and how many of them.

Efficiency Indexes

The special ASPROM software is made up of about 30,000 operators reduced to the Assembler language.

The system has been used in designing a number of microprogram devices of computer ASVT and SM. The adjustment of the system to each new microprogram base (the size of the FORMULYAR is 500 to 1000 lines) took approximately 1 man-month. The complete processing of one microinstruction in ASPROM (translation with input control and correction, producing the document, entry of changes by the results of checking out the sample) took 30 to 60 seconds of machine time on the M4030 computer.

The use of the system made it possible to accelerate the development of one controlling memory by 3 to 9 man-months. The annual cost benefit from the introduction of ASPROM exceeded 150 thousand rubles.

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METHOD OF COUPLING THE VIDEOTON-340 VIDEO TERMINAL TO THE INTEGRATED COMPUTER SYSTEM

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan/Feb 78
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[Article by V. P. Vinnitskiy, A. A. Sergeyev, and A. Ye. Lysenko]

[Text] Statement of the Problem

Among the broad set of remote data processing devices, the video terminals (VT) usually realized in the form of subscriber stations for the integrated system of computers play an important role. The Videoton-340 video terminals have found application in the data processing systems based on the second generation computers (Minsk-32, BESM-6). At this time the development of the remote data processing systems is proceeding along the path of using the means of the integrated computer systems. The coupling of the remote processing devices into the integrated system of computers is standardized. The Videoton-340 does not enter into the composition of the integrated system of computers as an independent device, and the video terminal similar to it is not being produced. The Videoton-340 has small size, high reliability, convenience when setting up and editing the text on the screen and in the control of the data transmission over the communications channel.

Among the remote control hardware for the organization of multichannel data transmission channels, the MPD-3 multiplexer is used. It includes up to four start-stop and (or) synchronous adapters designed for operation in the speed range to 48 K bits/sec with the AP-1, AP-3 and AP-70 type subscriber stations and the YeS-7920 display complex and also for organization of the intercomputer exchange. The MPD-3 does not have means of connecting a single compact video terminal over the telegraph or physical lines.

The demand for the organization of the coupling of the integrated computer system to the Videoton-340 through MPD-3 and the physical communications line has led to the statement of a technical problem: the development of the circuitry for coupling the Videoton-340 to the MPD-3. The GlavNIIVTs Institute of the Ukrainian SSR Gosplan has developed and implemented a method of coupling the above-indicated devices. The following restrictions have been imposed on the development of the coupling devices in order to minimize the expenditures of means and time:

For coupling to the video terminal it is necessary to use an adapter from the nomenclature of devices entering into the MPD-3 composition;

The logical and structural diagrams of the video terminals must not undergo any changes. This restriction is explained by the fact that modification of the functional diagram of the video terminal is inexpedient in view of the organizational and technical difficulties. Let us note that at the present time the circle of organizations having a Videoton-340 available for their use and modifying the computer complexes based on the integrated system of computers has expanded. The users desiring to couple the Videoton-340 to the acquired MPD-3 are provided an additional service by the manufacturing plant: modification of the MPD-3 adapter for coupling the Videoton-340 video terminal.

Method of Designing the Coupler

The initial conditions for designing the coupler are as follows:

Modification of the MPD-3 adapter must not disturb the algorithm for its operation with the subscriber stations indicated in the technical specifications;

Structurally the coupler must enter into the composition of the adapter in the form of an additional TEZ;

The software for the modified adapter must not undergo any changes when operating with the video terminal;

The parameters of the data communications channel are determined by the characteristics of the telegraph interface of the video terminal.

Peculiarities of the Functioning of the Videoton-340 Video Terminal

The presence in the video terminal of the telegraph interface (unipolar or bipolar) predetermines the use of the uncommuted start-stop telegraph for physical communication lines and exchange rates in the range of 50 to 1,200 bits/sec. Increasing the reliability during data exchange with the video terminal is ensured by the method of parity checking. The data in the communications channel are represented by the KOI-7N₂ character set (All-Union State Standard 19767-74), with the exception of the PUS, VSh, VT, KB, AN, KN, ZM, RI4-RI1 and ZB service symbols which are not transmitted to the computer and are not displayed on the screen. In the video terminal there is no function for automatic transmission of the register symbols on replacement of the registers, but the operator has the possibility of inserting these symbols into the transmitted text. The transmission of the data to the computer is provided for only by entire files without breakdown into blocks; the last transmitted symbol is the KT symbol indicating the end of the transmitted text and automatically putting the video terminal into the reception mode. The length of the message transmitted in one communications session is no more than 1280 bytes.

These design conditions and operating peculiarities of the video terminals impose restrictions on the type of adapter capable of ensuring an algorithm for exchange with the video terminal. The analysis of the technical parameters and the algorithms for the function of the MPD-3 adapters as applied to the characteristics of the video terminals allows the TA-1 telephone adapter to be chosen. The use of the TA-1 to organize communications with the video terminal gives the following operating conditions and parameters of the data transmission channel:

Uncommuted, single point communications channel with an exchange rate of 200 bits/sec;

A standard S2 junction realized in the TA-1 adapter for connecting the YeS-8001 modem is blocked, and in place of it, the SI-TG telegraph junction is organized;

Improving the reliability using matrix coding and automatic decision feedback must be blocked;

Control of the communications exchange algorithm is realized by the video terminal operator, and it depends on the type of read and write operations (with or without means of checking).

For the realization of this operating mode the coupler performs the following functions:

Simulation of the S2 junction circuits;

Mutual conversion of the telegraph messages and logical signals;

Blocking the operation of comparing the check sums on reception of the text;

Extinguishing the symbols of the check sums, the recording symbols, the service symbols KB and RE during transmission of the text.

Recoding of the KB service symbol into the PS or SU2 symbol depending on the type of monitoring of the transmitted modules: with automatic monitoring or monitoring respectively;

The extinguishing of the KT symbol received from the video terminal in the automatic read regime after the incoming KP symbol during operation without test means.

In accordance with the investigated functions with which the coupler is charged, we arrive at the structural diagram shown in Figure 1. The functions of the input logical assemblies indicated in Figure 1 are as follows:


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A: = READ ^ PMTEXT ^ YET KB, KT ^ 7 YET
    KSB ^ CLEAR GRPPT
B: = REAL, CLEAR √ (SB1 ^ TS1)
C: = READ ^ PM TEXT ^ YET KB, KT ^ SB9 ^ TS2
D: = WRITE ^ (YET KB, KT ∨ YET KSB)
E: = WRITE ^ 7 SB10 ^ TS2 ^ { (7 YET LAT ^
    GRPP[0]) ∨ (YET LAT ^ 7 GRPP[0]) }
F: = REAL, CLEAR √ (SB10 ^ TS2)
G: = WRITE ^ DSH KB ^ SB1
H: = ON √ SB10
J: = KP (DSH) ^ READ ^ PM TEXT
K: = ON √ DSH FF

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The telegraph transceiver is designed for mutual conversion of the DC telegraph sendings and logical signals of the series 155 integrated microcircuits. The basic element of the transceiver is the symbol image converter which ensures galvanic decoupling of the communications line and the logical elements of the system with respect to the power circuits. The use of the image converters increases the noiseproofness of the data transmission channel, and it decreases the effect of the telegraph units operating by the adjacent pairs of cables on the functioning of the system.

The component for shaping the pseudosymbol of the check sum of the module (KSB) and the pseudosignal of KSB comparison is designed for ensurance of the algorithm for the operation of the TA-1 telephone adapter in the RECEIVE TEXT mode given by the READ TEXT instruction. In view of the absence in the video terminal of a circuit for shaping and analyzing the KSB [module check sum], in the system made up of the Videoton-340 and the integrated computer system, the function of improving the reliability by using matrix coding and automatic decision feedback is excluded, but the previous exchange algorithm is simultaneously retained. This makes it possible not to modify the program means of remote processing as applied to the conditions of the investigated system and to use the channel programs of the READ and WRITE macroinstructions of the OTMD or BTMD OS YeS access method developed for the subsystem made up of the TA-1 telephone adapter and the AP-70 device on the noncommutable communications lines. On generation of the user software of the investigated system it is necessary to consider that the video terminal does not have the possibility of modular data transmission, for it does not appear possible to transmit the KB symbol to the communication line (in the video terminal the KB symbol code realizes the PRINT function--print out the contents of the video terminal buffer on the matrix printer). Therefore the message must be transmitted to the computer not module by module, but as an entire file bounded by the coupling symbols MT and KT or NT and KP.

For reception of the text from the computer terminal, the instruction READ is put out. The first arriving NT symbol converts the adapter to the RECEIVE TEXT mode and starts the KSB shaping circuit. Simultaneously with the reception and transmission of the information symbols to the input-output

channel the adapter stores the KSB. After reception and decoding of the KT symbol the accumulation of the KSB ends and the adapter waits for the arrival of the KSB symbol (the YeT PB, KT trigger is switched on). However, in the SEND mode (automatic transmission mode) the symbol transmitted from the video terminal to the KT is the classed character, after which the video terminal automatically switches to the ON LINE regime.

In view of the absence of the reception of the KSB symbol from the video terminal, it is necessary to lock the operation of comparison of the shaped and incoming KSB in the adapter. This is achieved by the introduction of the KSB pseudosymbol formed in the coupler by the YeT1 trigger into the adapter after reception of the KT. The most easily formed ZB symbol is selected as the KSB pseudosymbol. For its output to the adapter, the YeT trigger forms only the start bit coming through the OR circuit to the Ts104-M reception circuit (see Figure 1, component 2). The last operation on reception of the symbol from the communications channel is the output of the CLEAR GRPP signal, after which the adapter is ready for the reception of the next symbol. The CLEAR GRPP signal delayed on the St_{pulse} element for the duration of the pulse after reception of the KT symbol sets the trigger $YeT1:=1$ sending the start bit to the Ts104-M circuit. The start bit starts the bit and cycle signal shaping circuit in the adapter, realizing synchronization of the operation of reception of the symbol. The $YeT:=1$ setting takes place by the synchrosignal $Sb1 \wedge Ts1$ (end of the start bit).

After the operation of series-parallel conversion the KSB pseudosymbol is entered in the check sum register (GRKS), where the accumulated and received check sums are compared. In case of comparison the signal [0] GRKS is generated which fixes the absence of errors in reception. However, in reality the probability of accidental comparison of the accumulated KSB and the KSB pseudosymbol is 2^{-7} ; therefore the signal [0] GRKS will not be generated. In case of analyzing the KSB this leads to the formation of the state byte (BS) "KK, VUK, MALFUNCTION IN THE DEVICE" and the more precisely defined state byte (BUS) "ERROR IN THE DATA." The erroneous completion of the READ operation is blocked by the forced formation of the signal [0] GRKS-M, which goes to the KSB analysis system which fixes the successful completion of the READ TEXT operation (the BS "KK, VUK" and the null BUS are generated correspondingly). The signal [0] GRKS-M is shaped by the YeT2 trigger (the $YeT2:=1$ setting is made by the $Sb9 \wedge Ts2$ synchrosignal on reception of the pseudosymbol KSB) and through the OR element it goes to the system for analyzing the KSB.

As a result of blocking of the operation of the shaping and comparison of the KSB, the element of vertical control drops out in the matrix coding, but the element of horizontal control is retained--the parity check of the received signals. The presence of blocking the vertical control requires the use of communication channels with a large signal/noise ratio which have low sensitivity to the pulse interference. This requirement is achieved by selecting the telegraph signals in the communications line and the application of galvanic decoupling of the telegraph and logical circuits with respect to the power supply.

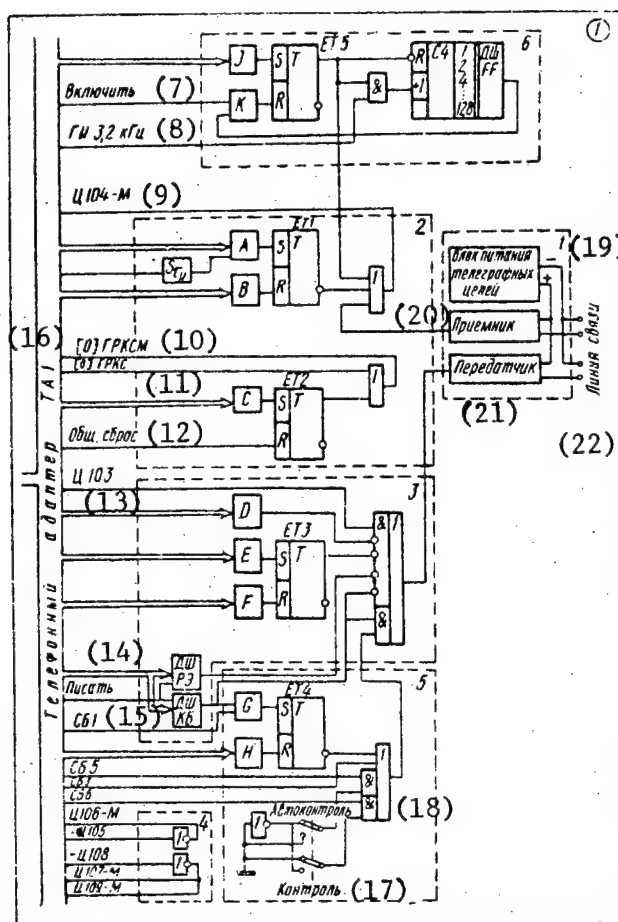


Figure 1. Functional Diagram of the Coupler: 1--Telegraphic transceiver; 2--Assemble for shaping for the KSB* pseudosymbol and the pseudo-signal for comparison of the check sums during reception of the text; 3--Assembly for forbidding transmission of the RUS, LAT, KB, RE service symbols and the KSB symbol to the communications channel; 4--Component for simulating the S2 junction circuits; 5--Component for recoding the KB symbol; 6--Component for forbidding the reception of the KT symbol during operation without test means in the automatic read mode.

Key: 7--On; 8--3.2 kilohertz; 9--Ts104-M; 10--[0] GRKSM; 11--[0] RKS; 12--Real clear; 13--Ts 103; 14--Write; 15--SB1; 16--TA1 telephone adapter; 17--Control; 18--Autocontrol; 19--Telegraph circuit power pack; 20--Receiver; 21--Transmitter; 22--Communication line.

*Module check sum.

The assembly for forbidding the transmission of the service symbols RUS, LAT, KB, RE and the KSB symbol to the communications channel is designed for exclusion of the above-indicated symbols from the transmitted data in the TEXT TRANSMISSION mode.

The introduction of the forbid function on transmission of the register symbols to the video terminal arises from the fact that the set of symbols generated by the video terminal permits their transmission on the same register in the KOI-7N₂ code. At the same time the adapter function is the conversion of the symbols received from the communications channel in the KOI-7 code to the KOI-8 code and back--on transmission to the communications channel. On reception of the symbols from the communications channel the conversion function consists in the addition of the register symbol to the shaped byte of the KOI-8 code: 0 (Latin register) or 1 (Russian register).

In order to indicate the conditions to the adapter for which it must shape one symbol or another, the source of the transmitted message must send a register symbol each time on replacing the register. For the video terminal the function of automatic transmission of the register symbols on replacement of the register is absent; therefore, on shaping the message sent to the computer the video terminal operator must manually (on changing the register) introduce the register symbol: before transmitting the capital Russian letters, the letter N* is written on the screen with simultaneous pressing on the CTRL keyboard (the keyboard for generation of the service communications symbols arranged in the 0th and 1st columns of the KOI-7 code table. Before transmitting the remaining symbols of the KOI-7 code to the screen it is necessary to enter the O* symbol code. The asterisk means that the service symbols depicted on the screen flash with a frequency of 5 hertz. The shaping and the editing of the sent messages are carried out in the autonomous OFF LINE mode.

When transmitting the symbols to the communications channel, the adapter constantly traces the 0 bit of the receiving and transmission register (GRPP) where the register flag of the symbol arriving in KOI-8 code is copied from the input-output channel. If the adapter detects a change in the register flag with respect to the preceding byte in the byte received from the input-output channel, then the transmission of this symbol to the communications line is automatically held up. The adapter is switched to the transmission mode in the register which is indicated by the 0 bit of the GRPP. Before transmission of the information symbol, transmission of the corresponding register symbol is organized. Then the information symbol is sent to the communications line in the KOI-7 code. However, as was indicated above, the video terminal does not react to the register symbols, and the generation of the received symbols and their representation on the screen are determined only by the code combination from the first to the seventh bits. The register symbols coming from the adapter and entering into the code combinations depicted on the screen interfere with the reception and analysis of the received text by the operator. As a consequence of what has been discussed above, at the time of formation of the register symbols by the adapter and

transmission of them to the communications line, the coupler forms the register symbol transmission forbid potential (the YeT3 trigger). The forbid potential is set until the output of the start bit of the register symbol to the communications line (the Tsl03 circuit). This potential is fed to the OR circuit, delaying the Tsl03 in the STOP state for the entire time of transmission of the register symbol (see Figure 1).

The KSB symbol transmission forbid is caused by the fact that in the video terminal there is no circuit for shaping and analysis of the KSB; therefore the KSB symbol coming after the KT symbol can be depicted on the screen. The code combination of the KSB symbol is a random variable, and on decoding this symbol in the video terminal, random symbols and control functions can be generated. As a result, distortion of the received information, destruction of it, error display in the received text, and so on can occur. In the TEXT TRANSMISSION mode the coupler provides for output of the KSB symbol transmission forbid potential to the Tsl03, establishing the STOP state in the communications line. This potential is generated at the time of decoding the KB (KT) symbol (the YeT KB, KT:=1 trigger) to transmission of the start sending of the KSB symbol, and it is cleared after establishing the stop sending in the Tsl03 (clearing the YetKSB trigger).

The service symbols KB and RE transmitted from the computer are interpreted in the video terminal respectively as the received text printout function (the tag is shifted to the initial position of the text) and the function to the clear the contents of the screen (the buffered memory of the video terminal is cleared). In order to eliminate this undesirable effect, in the coupler provision is made for an element to forbid transmission of the KB and RE symbols to the communications channel on execution of the WRITE instruction. The forbid element is a decoder of the GRPP states corresponding to the KB and the RE codes. The forbid potential goes from the decoder output to the OR circuit, keeping the Tsl03 in the STOP state.

In the investigated system the exchange algorithm corresponds to the algorithm for the functioning of the AP-70 with respect to the isolated communications lines. Here the user can organize the data exchange either by the long modules (arbitrary length) with control or autocontrol, or without division into modules (without control). In the first case the exchange algorithm is insured from the direction of the computer by the remote communications method of access, and from the video terminal side, by the operator. After reception of the data block, the operator of the video terminal must send the yes or no answer in the three second timeout. Since the KB symbol is not output to the screen, in the coupler provision is made for recoding of this symbol in the idle symbols depicted on the screen in order to inform the operator of the end of reception of the block.

In the AP-70 device when working with autocontrol the KB symbol is recoded into the PS symbol realizing the function of line conversion, for in this version the length of the block corresponds to the length of the transmitted line of text. The analogous function of conversion of the line exists also

in the video terminal (LINE FEED); therefore if the user has defined the operating mode with the autocontrol, then the coupler will have to provide for recoding the KB symbol to the PS symbol and output of the latter to the communications line.

If the operating mode with control is given, then for transfer of the tag to the initial position of the next row, the user outputs the PS (J*) symbol in the text transmitted to the video terminal. In this case the recoding of the KB symbol to the PS symbol leads to distortion of the image format. In order to eliminate this undesirable phenomenon when working with the control of long blocks, recoding of the KB symbol into the depicted symbol not performing any functions in the display and distorting the received information is introduced. For this purpose the code for the SU2 (R*) symbol is selected which serves only for information of the operator regarding the end of reception of the data block. The switching of the above-indicated modes is realized by "AUTOCONTROL-CONTROL" switch. If during data exchange the user does not provide for division of the transmitted text into blocks, then the recoding assembly has no effect on the operation of the system. In this case the transmission of the message ends with the KP symbol and the BS KK, BUK, OS is read in the computer.

The assembly for forbidding reception of the KT symbol during operation without test means in the automatic data read mode SEND is designed for exclusion of a malfunction on completion of reception of the message.

The algorithm for the reception of the message from the AP-70 in the operating mode without check means provides for use of the message format NT TEXT KP. After reception of the KP symbol the execution of the READ command ends with output of the BS "KK, VUK, OS" and the adapter is switched to the CONTROL regime. The next executed instruction can either be WRITE or SWITCH OFF. The reception of any symbol by the adapter in the CONTROL mode without the instruction at the time of initial access leads to a malfunction and immediate termination of the execution of the incoming instruction (the BS "KK, VUK, MALFUNCTION IN THE DEVICE" and the BUS "LOSS OF INFORMATION" are formed. In order to ensure the possibility of automated transition of the video terminal from the SEND mode to the data reception mode, the operator must form the message of the NT TEXT KP KT format.

When reading the data, the KT symbol will be the last symbol transmitted to the communications line automatically performing the function of switching The VT to the ON LINE reception regime. However, as a consequence of what has been stated above, this symbol must not reach the adapter. At the time of decoding the KP symbol, the coupler sets the trigger $YeT5:=1$ shaping the stop sending in the Ts104-M and starting the pulse counter. The time interval during which the STOP state is maintained in the Ts104-M must end after establishing the stop sending of the KT symbol in the communications channel. The required interval is ensured by decoding the ones state (FF) of the eight-bit counter. The clear pulse from the output of the FF decoder sets the trigger $YeT5:=0$ unblocking the Ts104-M reception circuit.

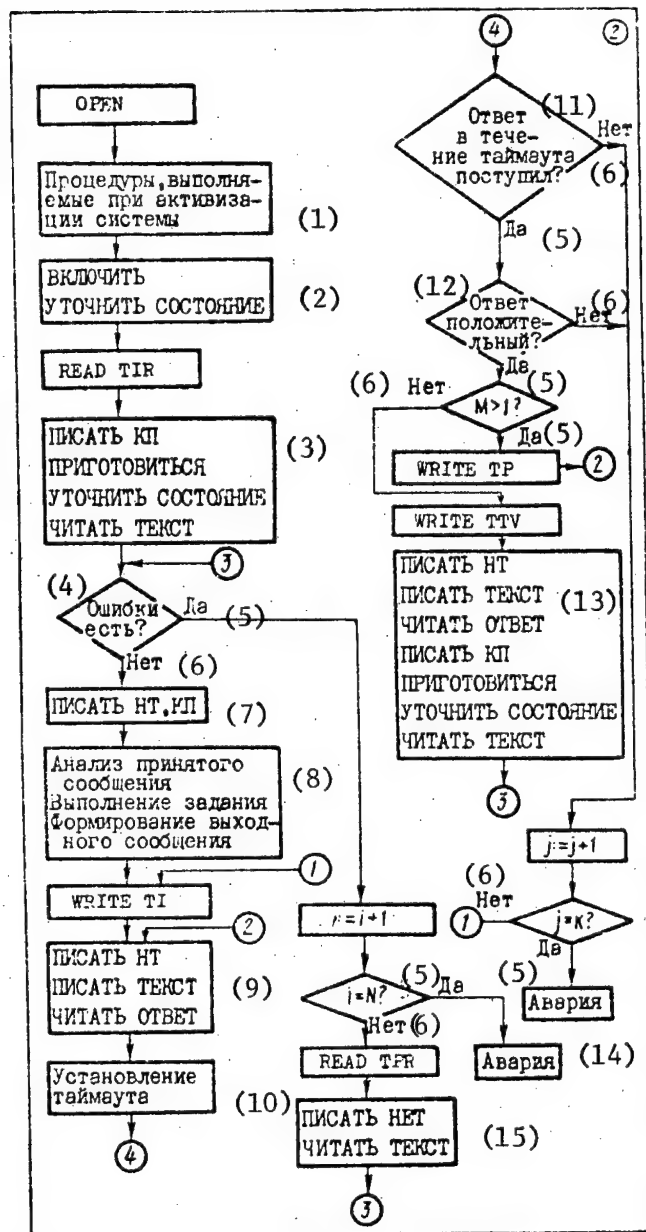


Figure 2. Operating Algorithm of the System in the Dialog Mode

Key: 1. Procedures executed during activation of the system; 2-- Switch on, pinpoint the condition; 3--WRITE KP, PREPARE, PINPOINT THE CONDITION, READ TEXT; 4--Errors?; 5--Yes; 6--No; 7--WRITE NT, KP; 8--Analysis of the received message, execution of the assignment, formation of the output message; 9--WRITE NT, WRITE TEXT, WRITE ANSWER; 10--Establishment of timeout; 11--Response arrived during the timeout; 12--Response positive?; 13--WRITE NT, WRITE TEXT, READ ANSWER, WRITE KP, READY, PINPOINT THE CONDITION, READ TEXT; 14--Emergency; 15--WRITE NO, READ TEXT

The assembly for simulating the S2 junction circuits is designed for ensuring the adapter operating algorithm during execution of the instructions SWITCH ON, SWITCH OFF and WRITE corresponding to the algorithm of the unmodified adapter.

Structural Design. The coupler is structurally a set of two TEZ: the logical and commutation TEZ. The logic of the coupler (the series 155 integrated microcircuits) and the transceiver are mounted on the logical TEZ. On the commutation TEZ there are jumpers permitting restoration of the initial connections between the TEZ of the unmodified adapter. The logical TEZ is inserted in the 27th plug of the TA-1 adapter panel, and the commutation TEZ, in the 28th plug. The unactivated (logical or commutation) TEZ are inserted in the 26th plug of the panel depending on the type of connected terminal of the Videoton-340 or the AP-70. During operation of the TA-1 adapter with the AP-70 adapter by replacement of the logical TEZ by the commutation TEZ, the connections are restored corresponding to the circuitry of the unmodified adapter. The initial functions of the adapter operation algorithm are restored correspondingly.

Tests. The above investigated coupler was manufactured by the authors and successfully tested when checking out the set of programs for remote dialog input of the assignments of the OS YeS version 4.0 in the system made up of the YeS-1040 and the MPD-3 (Ta-1) and the equivalent cable communications line of 18 km with the Videoton-340 video terminal.

Algorithm for Operation of System. In order to control the data transmission channel in the investigated system, the program means for remote processing of the OS YeS are used: BTMD or OTMD. The method of controlling the data transmission is given by the data transmission channel parameters (the start-stop uncommuted single point communication channels) and the error detection and correction procedure.

The individual differences in the functions and the possibilities of controlling the terminals determined the required modules of the control programs for the transmission of the messages entering into the BTMD or the OTMD OS YeS. The information on the modules is given during generation of the system and during the assembly time in μ DCB for the group of communications channels to which the video terminal belongs. Two versions of operation are possible in the system:

With means of checking the long modules of arbitrary length in the autocontrol or control regime;

Without check means.

On generation of the system as a function of the configuration of the remote processing system and the state of the communications channels, the systems programmer ensures one version or another of the functioning by means of inclusion of the corresponding modules for controlling the data transmission.

Let us consider the version of the functioning with the test means in the autocontrol regime (see Figure 2). Before executing the operations with respect to transmission of the data the OPE macroinstruction opens and activates the data file of the group of communications channels, it establishes and organizes the beginning of operation of the internal control modules, it loads the programs and tables from the system library required for construction of the channel programs of the READ and WRITE macros, it organizes the buffer pool for the message input-output and also it prepares the adapters of the multiplexer connected to the group of communication channels for operation (on the SWITCH ON instructions, the channels are put into the operating state).

The messages are transmitted by the READ or WRITE operations on execution of like macroinstructions. The operation of INITIAL READ WITH CLEAR (READ TIR) establishes contact with the video terminal and reads the first message into the buffer input region.

The establishment of contact with the video terminal means sending the KP control symbol (D*) from the direction of the computer, informing the video terminal operator of readiness of the computer for operation. The video terminal operator goes to the OFF LINE regime, prepares the first message for the computer and transmits it to the computer in the SEND mode (in the TA-1 the channel instructions PREPARE, PINPOINT THE CONDITION and READ are executed successively). The reception of the text and writing of it into the input buffer continue until the KT communication symbol arrives. If at the time of reception no error has been permitted when performing the parity check, the TEXT RECEPTION operation ends with output of the BS "KK, VUK" to the input-output channel, and the macroinstruction REAT TIR ends with output of the WRITE NT KP instruction putting the data transmission channel in the CONTROL mode and informing the operator of the video terminal of successful reception of the message or output of the response message prepared by the computer for transmission to the given terminal. If an error has occurred during reception, then the macroinstruction READ TPR will be output for repeated reading of the message. In this case the video terminal operator sends the NO answer indicating repeated output of the message in the SEND mode (the tag is converted in the OFF LINE mode to the initial position of the text, and the SEND key is pressed). The operation of REPEAT READ can be executed in the start-stop mode of operation twice in a row ($N = 2$), after which the data transmission channel is considered in the emergency state, and the message is output to the system console with indication of the group of communications channels and the number of the channel in the emergency condition. The received text in the buffer input region is destroyed.

On successful completion of the reception operation, the received message is analyzed by the remote message control program, it is edited, it is converted from the KOI-8 code to the DKOI and it is sent to the processing program of the user (the name of the receiver must be indicated after the heading of the message). On completion of the processing of the assignment, the program forms the output message and by outputting the macroinstruction WRITE TI (INITIAL WRITE) it organizes the copying of the message into the

output buffer, it establishes contact with the video terminal indicated in the prefix of the message heading, and this message is transmitted to the communications channel. The text of the message ends in the KT symbol (in case of being broken down into blocks, it ends in the KB symbol), after which the READ RESPONSE instruction is generated. The video terminal operator, receiving the NT (B*) symbol, waits for the arrival of the KT (C*) symbol or the KB (J* in the case of autocontrol, R* in the case of control) symbol. In the presence of the text on the screen of the video terminal bounded by the symbols B* and C* (or J* (R*)), and in the absence of errors (the PARR ERR display is not lit) the video terminal operator must send a YES answer (the CTRL and F keys are pressed simultaneously). If this condition is not satisfied, the NO answer is sent (the CTRL and U keys). The answer must be sent during the 3 second timeout; otherwise the instruction ends with generating the BS "KK, VUK, MALFUNCTION IN THE DEVICE" and the VUS "ERROR IN THE DATA." If the computer has received a YES answer, then the remote message control program checks the list of output messages ready for transmission to the given video terminal. If the number of such is $M > 1$, then the macroinstruction WRITE TT (CONTINUE TO WRITE) is generated, which is executed analogously to the above-described. If $M = 1$, then the macroinstruction WRITE TTR (CONTINUE TO WRITE WITH CLEAR) is generated, on successful completion of which the data transmission channel is set to the CONTROL mode. The last received KP (D*) symbol allows the operator to input a new message to the computer. However, it is more effective to end the transmission of the last message in the video terminal by generating the macroinstruction WRITE TTV (CONTINUE TO WRITE IN THE DIALOG MODE), which sends the last message to the video terminal, reads the response, then sets the adapter to the CONTROL mode, waits for the message from the video terminal and reads it. In this case, within the framework of one macroinstruction two operations are matched: WRITE TEXT and READ TEXT. When operating in the dialog mode the macroinstruction WRITE TTV output after the macroinstruction READ Tl, ensures output of the instruction WRITE NT as the positive answer to the previously received text. The video terminal operator, in response to the output of the macroinstruction WRITE TTV can either send a new message to the computer or end the communications session, sending the corresponding control instruction.

For deactivation of the system, the macroinstruction CLOSE is generated which ends the operation of the adapters (the SWITCH OFF instruction is generated), it frees the ready-access memory occupied by the buffer pool, it stores the controlling modules and tables to the form they had on generation of the OPEN macroinstruction. The operations of activation and deactivation of the system are initiated by the operator at the central control panel of the system.

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MODEL OF THE SYSTEM FOR COMPLEX AUTOMATION OF LARGE RESEARCH DEVICES BASED ON THE MINICOMPUTER NETWORK*

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan/Feb 78
pp 98-100 submitted 30 Mar 77

[Article by A. V. Kutsenko]

[Text] A basic characteristic feature of the large research units is that they are in the form of complicated complexes including many physical devices, hundreds of all-possible sensors and servomechanisms, electronic circuits, electromechanical drives and other elements which must operate smoothly and fail-safe in order to ensure fitness of the device. For this reason, for complex automation of such devices, the highest, fourth level of automation is required which includes the gathering and processing of the data, control and multiprocessor operation [1 to 4].

The cost of the investigated units is tens of millions of rubles; therefore, the times for introduction of them into operation and operating efficiency are acquiring primary significance here. Accordingly, the basis for the automation system must be the principles ensuring effective application of it both when checking out the device and during step-by-step development of it and parallel inclusion of many groups of specialists into the operation. The system must provide fail-safe operation of the equipment during operation and maintenance of the installation and it must allow for redundancy.

The system must have a flexible structure of both hardware and software, and it must provide for simple buildup of the system and adaptation of various problems without disturbing the means already created, by efficient use of them.

*Here the concept of a "model" is used for informal generalization of the information pertaining to the structure, operation and maintenance of the systems for complex automation of large research devices.

The concentrated nature of the devices, their awkwardness, the abundance of information points and the presence of powerful interference are advancing additional requirements which must be considered when designing the automation system: namely, the system must ensure optimal distribution of the computer reserves and creation of the required communication channels between them; the processing and compression of the information must be done by multiple use of standard means; on organization of the information flows it is necessary especially to consider the problems of noise protection.

The enumerated requirements can be satisfied if when designing the automation system, the following basic principles are used:

1. The system is designed to be a multiprocessor system. It is constructed by the ideology of the minicomputer network [5] with the application of the individual processors for solution of simple problems.
2. The measuring control equipments, its coupling to the minicomputers and peripheral devices is executed according to the CAMAC standard.
3. The separate components of the system are put together in the form of remote stations and they are arranged in direct proximity to the functional components of the physical unit.
4. The data exchange, including exchange between processors, must be realized over the main line of the crate, by the "drive-drive" principle [4].
5. The information must be exchanged with the remote stations over the series ring CAMAC main [6].
6. In the main line for connection to the remote stations, sections of optical data transmission lines are provided.
7. The system must provide for connection with remote computer reserves for which a second ring main is provided.
8. The system includes developed dialog media for communication with the operator based on applying alphanumeric, graphical and color displays.
9. The system must provide for documenting the basic processes of the device on magnetic tape.
10. The system software must include the following:

The software for the individual minicomputers carrying out simple, only slightly related missions;

The system software as a whole with "transparency" of the data transmission paths when it is necessary for the system partners to reference each other.

On the basis of the formulated principles, a model of the automatic system is constructed which is presented in Figure 1. The model provides for the separation of the general problem of automation into a series of simple subproblems and realization of the independent subsystems on the basis of the individual minicomputers. The processors of the individual subsystems are related to each other by the "drive-drive" principle, thus forming the multiprocessor system which operates with a common user field. The time-space transformation of the computer reserves is realized by the successive data transmission lines. The processes are specialized to a greater or lesser degree, which lends the system new characteristics and ensures new capabilities.

The system constructed by the proposed model is variable with respect to its nature, and it can be adapted to the specific requirements and conditions.

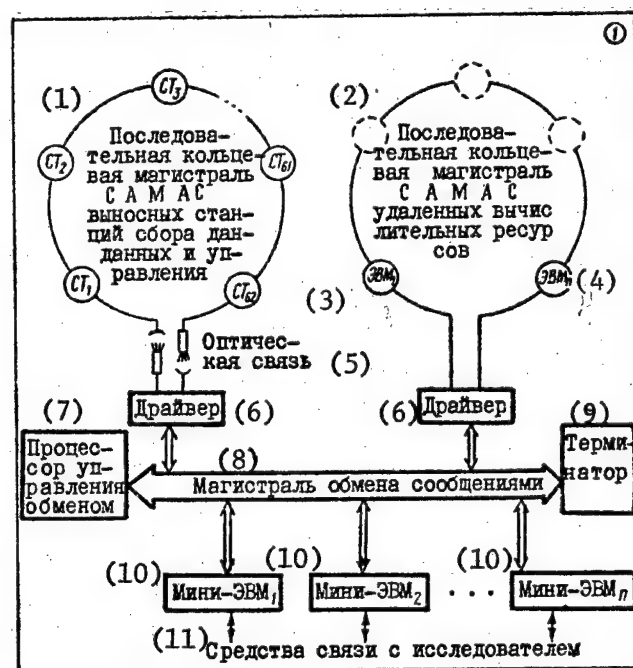


Figure 1. Model of the System for Automating Large Series Units.

- Key:
1. Series-connected ring main of the CAMAC remote data gathering and control stations;
 2. Series-connected ring CAMAC main for the remote computer reserves;
 3. Computer₁;
 4. Computer_n;
 5. Optical coupling;
 6. Driver;
 7. Controlled exchange processor;
 8. Communications exchange lien;
 9. Terminator;
 10. Minicomputer
 11. Means of communication with researcher

The realization of the design requirements imposed above in the framework of the proposed model can be accomplished, in particular, as a result of the following properties and characteristics of the hardware and software of the automation system.

1. The application of a network of minicomputers instead of one computer leads to the possibility of the performance of the assignment requiring fast solution by several processors working simultaneously on one problem; ensurance of autonomous operation of each subsystem of the device; ensurance of parallel checkout, introduction into operation, preventive maintenance and improvement of the subsystems, which offers the possibility of involving a large number of executive agents in the operation.

2. The application of the "drive-drive" principle permits each processor to refer directly to any of the rest. In case of failure of any of the processors, its functions can be taken on by the remaining ones; in addition, each minicomputer can have minimum configuration as a result of the possibility of referencing the common memory and the common peripheral devices of the system.

3. On the basis of the fact that the processors operate on the general field of the users, each processor can reference any measuring or control module located at any location in the device, and each module can reference any processor by addressing the successive line through the message protocol.

4. The application of CAMAC ideology leads to the possibility of outfitting and subsequent development of a system as a result of the ready purchaseable modules with minimum special development of the equipment and the possibility of simple adaptation of the system to various problems. This, in turn, leads to minimization of the time required to put the system into operation.

5. The use of a series line permits the use of large computers, ensuring a data transmission rate of up to 30M bits/sec. The spacing is not limited, and it is determined only by the presence of 9-channel communications line. The possibility of minimizing the computer means and the manpower reserve in the system itself provides for communications with remote computer reserves.

6. The use of the systems crate as the exchange line ensures economical solution of the exchange problems and the control of any of system processors which are connected to the crate through the auxiliary module station. The simplicity of the systems crate facilitates 100 percent redundancy of it.

7. The operating reliability of the system is ensured by the fact that the processors are operatively interchangeable. The components of the device, the modules and subsystems as a whole are monitored by one of the processors by the corresponding programs. The monitoring and correction of the errors in the successive lines is realized with a high degree of reliability as a result of the application of the geometric code. The protection from electrical interference is realized by inclusion of optoelectronic sections of the transmission lines with the application of glass fiber light guides.

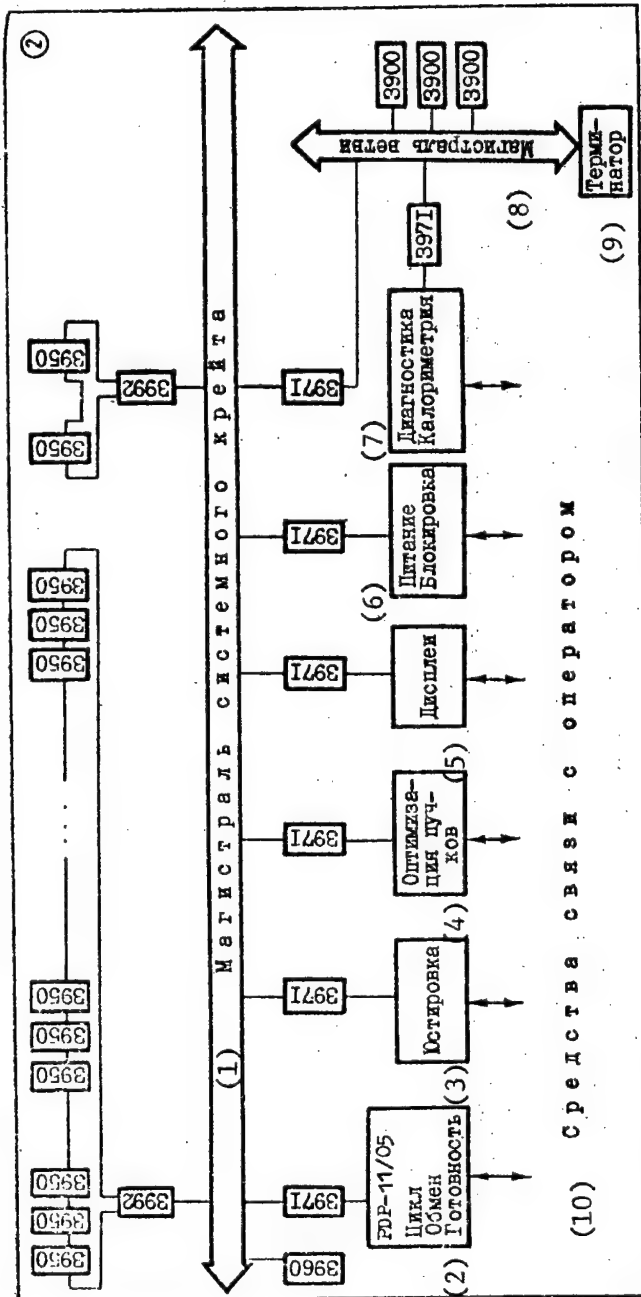


Figure 2. Structural Diagram of the System Based on the Kinetic Systems Modules

Key:

1. System crate line;
2. Cycle, exchange, availability;
3. Adjustment;
4. Optimization of the beams;
5. Displays;
6. Power supply, blocking;
7. Diagnostics, calorimetry;
8. Main branches;
9. Terminator;
10. Means of communication with the operator

The systems modules manufactured by the Kinetic Systems Company [7] organized on the basis of a system crate or the standardized data exchange line (UMSO) and the corresponding systems modules developed at the Institute of Automation and Electrometry of the Siberian Department of the USSR Academy of Sciences [8] can be used as the basic technical means for implementing the model at the present time. The minicomputers of any model can be used as the processors. The servomodules of the CAMAC standard are selected in accordance with the problems.

The investigated model was used as the basis for the development of the automation system design for a powerful laser. The structural diagram of the developed system is shown in Figure 2. It is a version of the system based on the Kinetic Systems modules. The types of modules are indicated by the numbers in accordance with the company designations.

Other versions can be investigated, among which the most interesting is the application of microprocessors on the remote stations. The analysis of the possibility of the application of microcontrollers such as the MACAMAC of the Borer Company (Federal Republic of Germany), the JCAM-10 of the Schlumberger Company (France), the microprocessor 9880 of the Kinetic Systems Company, the CAM 1.15-1 of the KFKI Institute (Hungary) for the investigated model demonstrated that this solution has a number of advantages determined by the transfer of the computer reserves to the direct proximity of the functional components of the device.

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SOFTWARE OF THE RADIUS SYSTEM

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan/Feb 78
pp 101-103 submitted 30 March 1977

[Article by V. A. Sidorov, B. L. Sysoletin, B. N. Shuvalov]

[Text] Introduction

In the experiments in high-energy physics performed at the Nuclear Physics Institute of the Siberian Department of the USSR Academy of Sciences, broad use is made of the M6000 minicomputer. The expansion of the possibilities of the machines is achieved by including them in the RADIUS system. The first segment of the central computer software provides for the creation of libraries of program and working files on discs and access of the peripheral machines to these libraries.

System Hardware

The structure of the RADIUS system is demonstrated in Figure 1. The Minsk-32 base computers and the central M6000 computer to which two YeS-5052 magnetic disc storages are connected are located in the computer center of the institute; the peripheral M6000 are in direct proximity to the experimental setups. One of the peripheral machines is installed at the computer center and is used for the preparation and checkout of the software. Like the central computer, it has two of the YeS-5052 magnetic disc storages. This permits programs to be prepared both for the central computer and for the peripheral machines under the conditions of around-the-clock preparation of the entire system.

The central M-6000 controls the access of the peripheral machines to the program bank and the data stored on magnetic tapes and also to the Minsk-32 computer. The system archive is stored on the magnetic tapes of the base computers and is copied into the central computer during initial loading of the system. The coupling between the central and peripheral M6000 is realized by means of special interfaces through the program channels. The base computers are connected to the central computer through a coupler executed from the ASVT-M standard. The coupler provides independent connection of the

central computer to eight subchannels of the Minsk-32 multiplexor channel. Four subchannels are used for communication in each Minsk-32 computer.

A more detailed description of the hardware of the RADIUS system is presented in [1].

Central Computer Software

The software of the central computer is made up of auxiliary software for preparing the system for operation and basic software on which the system operates jointly. The auxiliary software includes independent programs for preparing the disc packets, generating the basic software and restoring the system. The described software is designed for the M6000 computer with 8K of ready-access memory words and it services up to six peripheral M6000 computers.

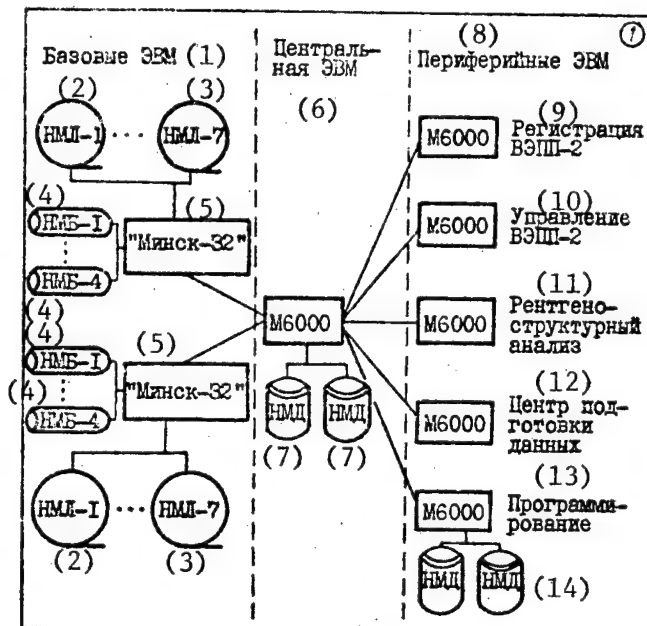
During generation of the system, the movable program modules of the basic software are loaded, the working tables are created, and the free memory is broken down into zones from which a succession of empty buffers is made up. For each peripheral computer a library is created on magnetic tape. During initial loading these libraries are filled with the programs of the peripheral machines. On restoring the system the libraries can be modified. In addition to the programs, each library can contain up to 15 working files. A working file differs from the program in that writing in it is allowed.

The basic software of the central computer is the set of program modules connected to each other and adjusted to the specific configuration of the auxiliary program generation computer. A brief description is presented below of the purpose of each module.

The supervisor provides for exchange with all of the external devices of the central computer (including peripheral and base computers). Exchange can be initiated both by the working modules and the active external devices. The operator panel, the peripheral and base computers belong to the active external devices of the central computer. On receiving a request from the active device, the supervisor isolates a free buffer and after reception of the block of data it places the filled buffer in sequence to the corresponding working module. The exchanges with active and passive external devices are combined with the execution of the working modules. In addition, the supervisor controls the correctness of exchange, and in the presence of errors it prints out the diagnostic message.

The planner organizes the multiprogram execution of the working modules. In the case of a halt or completion of execution, at the beginning or end of exchange, the planner provides for the table of operating modules, it selects the module ready for the beginning or continuation of operations and starts it.

The working modules process the requests of the active devices of the central computer. All of the requests formed into standard modules have an indicator (number) defining the processing operating module. Each module processes some class of request. The numbers of the working modules are rigid in the sense that they are used by the operating programs of the peripheral computers and on changing the number of the module, modification of the operating program is required. The maximum number of modules is limited by the ready-access memory size of the central computer.



Structure of the RADIUS System

- Key:
- | | |
|------------------------------|---------------------------------|
| (1) base computers | (8) peripheral computers |
| (2) magnetic tape storage-1 | (9) VEPP-2 recording |
| (3) magnetic tape storage-7 | (10) VEPP-2 control |
| (4) magnetic drum storage... | (11) X-ray diffraction analysis |
| (5) Minsk-32 | (12) data preparation center |
| (6) central computer | (13) programming |
| (7) magnetic disc storage | (14) magnetic disc storage |

Номер слова (1)		②
1	Длина данных (2)	(3) Признаки
2	"Кому" (4)	(5) "Кто"
3	Операция 1 (6)	
4	Операция 2 (7)	
5	Собственно данные (8)	
...		
L + 5	Контрольная сумма (9)	
L + 6	Дополнение (10)	

Structure of the Data Module

- :
- | |
|------------------------|
| (1) number of the word |
| (2) length of data |
| (3) attributes |
| (4) to whom |
| (5) who |
| (6) Operation 1 |
| (7) Operation 2 |
| (8) data itself |
| (9) check sum |
| (10) supplement |

Coupling to the Peripheral and the Base Computer

All of the exchanges with the active external devices of the central computer are made by the standard formed modules with respect to a united algorithm. The coupler with the base computer processes one of the M6000 words in 50 microseconds, and the exchange with the peripheral machines is carried out with a rate of one word per 100 microseconds.

The standard data block (Figure 2) is made up of a title of fixed size (8 bytes) and the data itself, the length of which can vary from 0 to 255 M6000 words (the M6000 word is made up of two bytes). The block contains the following fields:

The data length--the number of words of data in the block;

Attributes--the service information for the processing modules;

To whom--the number of the receiver module;

Who--number of the transmitter module;

Operation 1--first two bytes determining the action of the processing modules;

Operation 2--second two bytes determining the action of the processing modules;

Data itself--data to be processed;

Check sum--modulo 65736 sum of all preceding words of the block (not written in memory);

Supplement--used only for exchange with the base computers for supplementing the block to the total number of words of the Minsk-32.

The exchange by the data blocks is realized in the following way:

Operation of transmitter	Operation of receiver
Output of "coupling request" instruction	Reception of "coupling request" instruction reserving of space for the block and transmission of the "request accepted" instruction
Reception of the "request accepted" instruction and transmission of the data block	Reception of the data block with calculation of the check sum
Transmission of the check sum	Reception and comparison of the check sum
Transmission of the "end of exchange" instruction	Reception and transmission of the "end of exchange" instruction
Reception of the "end of exchange" instruction	

If the receiver or the transmitter detects a failure, it puts out the "error" instruction on the line. The communications are not shut down, and in case of repeated error during the current communications session the exchange can repeat up to five times. In the case of a larger number of errors communications cease.

Software of the Peripheral Computer

In each peripheral computer the basic part of the ready-access memory is allocated for special software. When creating the software of the peripheral computer of the RADIUS system two goals were pursued: as complete as possible use of the capability of the central computer data bank and at the same time reduction of the system expenditures of ready-access memory to a minimum.

Considering the possibilities of the system, the user of the peripheral computer can store programs in absolute format in the library on a disc, load and execute the programs with respect to the operator directive, break down the programs into several overlapping segments, create working files on the disc and finally transmit data to and accept data from the Minsk-32.

The software of the peripheral computer is made up of the resident part which is constantly in the ready-access memory and several segments stored on the disc and called when necessary. The resident part includes the monitor and the driver of the communications with the central computer. The segments are divided into two groups loaded in different overlapping domains: processors and drivers. In the first version of the software there are two processors (directive and interrogation) and four drivers (output to teletype, input from the teletype keyboard, input from the photoreader and output to the punch). The reference to the drivers is the same as to the standard drivers for absolute programs.

The possibility of storing absolute programs in the library on disc permits the absolute program to be broken down into the main part and several overlapping segments which significantly increases the possibilities of the program and reduces the consumption of the ready-access memory. Thus, as a result of segmenting the software of the peripheral computer, the system area occupied a total of 1K words. The programs operating in the vicinity of the basic control system (BCS) can also be broken down into the main section and several segments loaded from disc into one overlapping region. Each segment is formed as an individual program. The communications with the main program are through external references. When obtaining the absolute version of the segmented program, small changes were made in the transposable loading and the BCS.

At the present time programs are working in the RADIUS system for gathering data during experiments on counter beams [2], accelerator control [3], processing of the data from x-ray diffraction analysis [4]. The disc operation system (DOS) of the M6000 operates on the computer for programming.

Prospects for Development

The further development of the software of the RADIUS system will take place in two directions: expansion of the functions in the central computer and development of the software of the peripheral computers. The second version of the software of the central computer, in addition to the functions described in this paper, will also provide for the users to work with personal libraries. The personal libraries can contain arbitrary files (programs in the initial and machine languages, arbitrary texts and data). The user can work with his library with any peripheral machine.

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GEOPHYSICS, ASTRONOMY AND SPACE

COMMENTARY ON 'SALYUT-6' BIOLOGICAL RESEARCH

Moscow PRAVDA in Russian 2 Aug 78 p 3

[Article by Academician K. Sytnik and Doctor of Biological Sciences V. Kordyum: "'Salyut-6'--'Soyuz-29'--'Progress-2': Our Commentary. Space and the Living Organism"]

[Text] It has already been reported that V. Kovalenok and A. Ivanchenkov are conducting a series of biological experiments on board "Salyut-6." The scientific and practical significance of them will be discussed below.

The development of space biology is characterized by a transfer of emphasis to the indepth study of the delicate mechanisms active in an organism. This was preceded by long and arduous work.

The evolution of life on our planet has occurred under the effects of gravity, which has, to a large measure, determined the structure of organisms, many features of their movement and a number of reflexes. Therefore, before flights were made into space, it was unclear whether living matter could exist given changes in basic geophysical factors. The efforts of a number of collectives of the USSR Academy of Sciences, the USSR Ministry of Health and other organizations have resulted in a positive response to this fundamental question. It was this significant finding that opened the road for mankind to space.

Then began the stage of studying the growth, structure and functional characteristics of cells under the conditions of space flight. At this time new collectives, including the Ukrainian Academy of Sciences' Institute of Molecular Biology and Institute of Botany imeni N. G. Kholodnyy, began work in the field of space biology. And the concept of biological relative flight time was formulated.

One and the same period of time can vary in significance depending on the organism. Thus, a month in flight is a little less than 1/1000 of the lifetime of man. For a white mouse, the same time span constitutes already 1/30 of its life and, for drosophila or arabidopsis, an entire cycle of development from birth to death. And for microorganisms,

a month is an entire "eternity" inasmuch as hundreds of generations emerge in that time. Therefore, the results of an experiment depend to a large extent upon the features of the selected subject in general and, in particular, its life cycle.

In the end, of course, the biological experimentation on flights is connected with man. Thus, microorganisms in given experiments function as models. Inasmuch as the fundamental molecular-biological processes are largely similar in lower and higher organisms (including man), information on single cells can be used--with qualifications--to predict the consequences of long-term space flight for man.

The selection of subjects from various levels (bacteria, single cell green algae, higher plants) makes it possible to study the effect of real space flight on various forms of organisms in the process of their individual development as well as in a culture of cells and tissues. This type of experimentation makes it possible to determine the stability of cells and their ability to adapt to change, which is the basis of evolution. Analysis on a subcellular level makes it possible to judge the functional characteristics of cell organelles and the intensity and direction of metabolism.

In the Ukrainian Academy of Sciences' Institute of Molecular Biology and Institute of Botany a new technology was created to make it possible to cultivate microorganisms in space and subsequently to analyze the test material in laboratories. Special equipment was prepared for this. A series of experiments conducted on more than 10 artificial earth satellites and transport ships showed that the conditions of space flight have a significant effect on the growth, reproduction, structure and metabolism of bacteria and effect on the growth, reproduction, structure and metabolism of bacteria and plant cells that remained physiologically active throughout the experiment.

The purpose of these experiments in space is, in the end, to reveal a regular pattern of behavior for an organism in weightlessness, to establish the mechanisms of its effect on living substances and to develop, on the basis of this, new means for controlling life processes. Thus, within the framework of the Franco-Soviet "Cytos" experiment program, on board the "Salyut-6" orbital station ciliated Infusoria paramecia from Toulouse and *Proteus vulgaris* from Kiev are being grown simultaneously. The final stage of preparation for this experiment was conducted in Moscow at the USSR Ministry of Health Institute of Biomedical Problems.

Of particular value to the experiment is the fact that both subjects are growing simultaneously in a single device under strictly-controlled constant temperature and parts of the material can be fixed at carefully determined time segments. At the present time, data from this experiment is being processed. A complete analysis will take much time; however, initial results have revealed a number of variations in cells of bacteria grown in space (the paramecia are being processed by the French).

At present, these variations have been surfaced due to biochemical and ultrastructural indications and, after all analyses have been completed, will evidently make it possible to make a conclusion on several of the delicate mechanisms of the effect of space flight on the developing cell.

All living substances can be divided into two large groups according to how their hereditary apparatus is organized--organisms with a differentiated nucleus and those without. Bacteria belongs to the second category. Our previous studies conducted on bacteria grown in space and tests conducted in accordance with the Cytos program made it possible to establish the dependence of bacterial growth in space on the conditions of cultivation. Already today it is possible to speak about what must be done to accelerate or slow down the rate of growth of given microorganisms in comparison with the controls on earth.

Another biological experiment on board "Salyut-6" was conducted with chlorella. It has been well studied over the past decade and promises to be instrumental in studying the effect of space flight on the structural and functional organization of cells, their growth and metabolism. This material is still presently being processed, and only initial results can be discussed. They have indicated that there was a significant intensification of algae growth in space as compared to the controls.

Alga belongs to the group of organisms with differentiated nuclei. Studies with such subjects in space are methodically more complex than with bacteria. Therefore, factual material is necessarily being accumulated in order to ascertain the regular biological processes of a given group of organisms in space. The results obtained from the "Salyut-6" flight are the first of such material.

It follows to add that when compared with earlier studies, those conducted by Yu. Romanenko, G. Grechko, A. Gubarev and V. Remek were of a higher order, a consequence of their record time in space flight. Long-term experiments that allowed for multiple generations to arise were conducted on a variety of organisms. They will make it possible to supplement significantly conceptions about the mechanisms active in cells under space flight conditions.

Growing higher plants in space is exceptionally difficult. And although this was successfully done by Soviet researchers in the special "Oasis" hothouse, there are many questions left to be answered. Therefore, in order to solve some concrete questions, another approach not requiring any kind of technical solutions was used. There is a group of subjects with retarded biological processes known as "storage organs." To this category belong tuberous (for example, potatoes) and bulbous plants. As a model for higher plants, the viper onion, whose tuber contains the rudiment for a flower cluster, was selected. It proved to be suitable for studying the effect of real space flight on the generative organs of plants. Comparative studies of test and control plants have shown an acceleration in the development of pollen grains in the buds of test tubers.

At the present time, V. Kovalenok and A. Ivanchenkov are conducting experiments which will make it possible to supplement and clarify data obtained earlier. Biological experiments in space serve to solve strictly practical and concrete problems. Relevant to this are data obtained to aid the development of life support systems for long-term manned space flights. Knowledge about the reaction of an organism to weightlessness will open future prospects for controlling some biotechnological processes beyond our planet. Ultimately, the discovery of new ways of affecting living organisms will make it possible to control biological processes for the benefit of various sectors of the national economy. Thus, the acceleration of cell growth in several microorganisms under space flight conditions has been discovered; clarifying the mechanisms providing the basis for this phenomenon will make it possible to produce them under earth conditions, which is very important for the microbiological industry.

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SELECTIVE EFFECT OF LASER IRRADIATION OF MATTER

Moscow USPEKHI FIZICHESKIKH NAUK in Russian Vol 125 No 1, May 78 signed to press 18 Apr 78. pp 57-96

[Article by V. S. Letokhov, Institute of Spectroscopy of the USSR Academy of Sciences, Troitsk (Moscow Oblast), in memory of Rem Viktorovich Khokhlov]

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1. Introduction

The creation of laser sources of coherent light with adjustable radiation wave length has opened up the possibility for selective excitation of

in practice any quantum states of the atoms and molecules with excitation energy in the 0.1 to 10 eV band. In the entire range of wave lengths from 2000 Å to 20 microns it is now possible to obtain coherent emission with a power sufficient for excitation of a significant portion of the atoms and molecules to the selective quantum state. This qualitatively increasing level of quantum electronics has made it possible to start systematic studies of the selective effect of laser irradiation of matter in 1969 to 1970. One of the most important and primary problems here is unconditionally laser separation of isotopes. An exceptionally important role in nuclear engineering and power engineering of materials with isotopic composition distinguished from natural composition and also significant deficiencies of all of the existing methods of separating isotopes, on the one hand, and the theoretical possibility of the development of new laser techniques, on the other, have opened up a very attractive field of activity for scientists and engineers. It combines the use of the latest data on the structure of atoms and molecules and their interactions with coherent laser radiation and the latest achievements in the field of tunable lasers with the explicit practical problem of finding and developing new methods of separating isotopes which will be cheaper, more productive, more flexible, less labor-consuming, and so on than the existing methods. Many hundreds of scientists are now working at dozens of laboratories of a number of countries in this urgent field. After the first several pioneer experiments in 1969 to 1972, hundreds of papers have been published directly on this problem by the present time. The discussion in the majority of them is presented in the first brief surveys [1-3] and then more details in the surveys [4-8].

The limited size of this article prevents discussion of lasers with tunable frequency which are essentially the basic experimental means of all of the methods of laser separation of isotopes. We shall limit ourselves only to an enumeration of the most important characteristics of laser emission which make the laser an extraordinarily valuable and efficient tool in this field of research:

- 1) Tunability of the radiation frequency, which permits us to obtain radiation on any frequency in the infrared, visible or ultraviolet range and recently in the VUV range of the spectrum;
- 2) High intensity sufficient for absorption saturation of the quantum transitions, that is, for excitation of a significant portion of the atoms or molecules;
- 3) Short (controllable) duration of the radiation which can be made shorter than the lifetime of the excited atomic and molecular states;
- 4) Spatial coherence of the radiation which permits shaping of the directional radiation beams and irradiation of extended volumes of matter;

5) Monochromaticity and time coherence which will permit achievement of extraordinarily high selectivity of the excitation with a negligible difference in the absorption frequencies of the separated elements.

The combination of all of these valuable properties in the practical source of optical radiation is opening up serious prospects for the development of the methods of selective effects by optical irradiation of matter on the atomic and molecular level.

2. Objects of Selective Laser Photophysics and Photochemistry

The term "selectivity" in laser photochemistry and photophysics has two values. First, we can talk about the selective photochemical version of molecules of one variety in a mixture with other molecules. This selectivity can be called "intermolecular." For example, it always exists when we are talking about the photochemical separation of isotopes. Secondly, it is theoretically possible to talk about the selective photoexcitation of any one molecular bond. If we insure chemical reaction with such a molecule before excitation relaxation with respect to many of the molecular bonds, it is possible to hope to control the photochemical reaction in a selective direction. This selectivity can be provisionally called intramolecular. It can be realized only in the chemical reaction with an acceptor sensitive not only to the energy, but also to the type of molecular excitation. This possibility of selective laser photochemistry has still been little studied experimentally. Therefore, using the term "selectivity" below, we shall almost always have in mind "intermolecular selectivity."

The basic processes of the selective effect by laser irradiation of matter which frequently is called "selective laser photophysics and photochemistry" are the following:

I. Selective separation of materials on the atomic-molecular level.

II. Selective chemical reactions with atoms or molecules of a selective variety (photochemical separation) or in the given direction (photochemical synthesis).

III. Selective detection of atoms, molecules or molecular bonds.

The basis for the selective effect by laser irradiation of matter is the difference in the absorption spectra of the atoms or molecules permitting selective excitation of the atoms, molecules or molecular bonds of the selected variety. The difference in the absorption spectrum is caused by the difference of certain of the following characteristics of the atoms or molecules:

- 1) Chemical composition;
- 2) Spatial structure;

- 3) Isotopic composition;
- 4) Isomer composition of nuclei;
- 5) Mutual orientation of nuclear spins.

Therefore theoretically, using laser radiation it is possible to realize the enumerated processes I to III (separation, chemical reactions, detection) in matter on the atomic-molecular level selectively with respect to various chemical elements, molecular bonds, isotopes, nuclear isomers, molecular stereoisomers, ortho and paramolecules, and so on.

Although at the present time the greatest attention has been given to the isotopically selective chemical reactions of separation of isotopes, the developed processes are theoretically applicable to all of the enumerated objects of selective laser photophysics and photochemistry. In addition to the selective chemical reactions and selective separation of materials on the atomic molecular level, the process of selective detection of atoms, molecules or molecular bonds is very important. This entire variety of processes of selective laser photophysics and photochemistry is depicted highly provisionally in Fig 1 where the types of selective processes are indicated along the horizontal, and their objects, along the vertical. It is true that it is necessary to consider the significant conditionality of this classification. For example, for the photochemical reactions, the selectivity can be understood as selective participation in the reaction of the selected atoms or molecules or selective participation in the reaction of any bond of the molecules for directional chemical synthesis. The division of the objects of the selective processes into molecules and molecular bonds is just as conditional, but useful. By the molecular bonds we mean, for example, the sections of micromolecules.

The isotopically selective photophysical and photochemical processes are now developing quite intensely. The reports at the last international conferences on lasers and their applications clearly indicate the continuing rapid progress in this field. There is hardly anyone now who doubts the high prospects for science and engineering in this area. In the given article a sketch is given not only of the methods but also the future, less obvious applications of selective laser photophysics and photochemistry. A study will be made of the prospects for the development also of certain nonisotopic selective photoprocesses indicated in the sections outlined in Fig 1. The choice is limited to the selective photoprocesses, the realization of which, in my opinion, opens up quite new possibilities in a number of adjacent disciplines: nuclear physics, spectroscopy, molecular biology, chemical technology, and biochemistry. Some of the processes investigated below, such as laser decoding of the series of nucleotides in DNA and laser selective biochemical processes are no less important than laser separation of isotopes [7, 114].

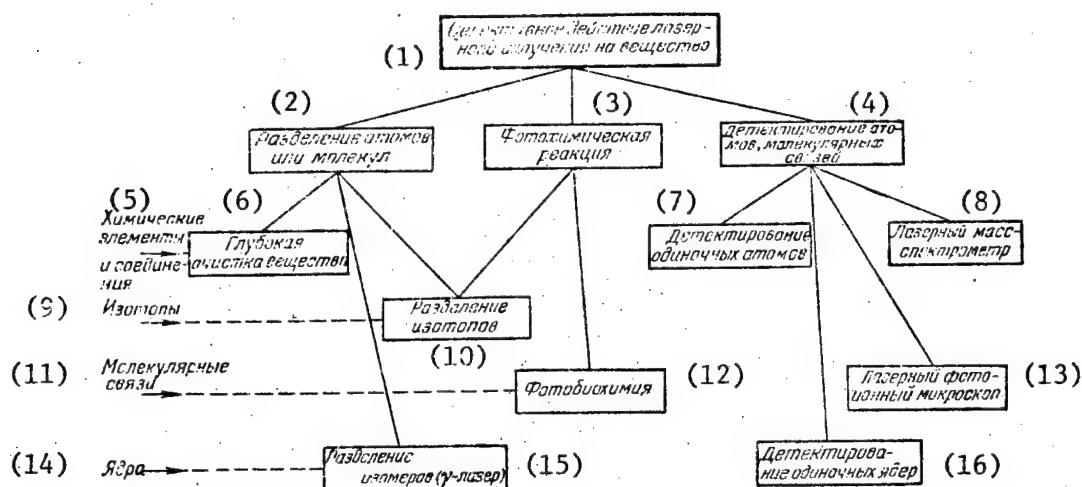


Figure 1. Types and areas of application of processes of selective laser photophysics and photochemistry

Key:

1. Selective effect of laser emission on matter
2. Separation of atoms or molecules
3. Photochemical reaction
4. Detection of atoms, molecular bonds
5. Chemical elements and compounds
6. Deep purification of matter
7. Detection of single atoms
8. Laser mass spectrometer
9. Isotopes
10. Separation of isotopes
11. Molecular bonds
12. Photobiochemistry
13. Laser photoion microscope
14. Nuclei
15. Separation of isomers (γ -laser)
16. Detection of single nuclei

3. Elementary Selective Photoprocesses

In connection with the problem of the separation of isotopes in the last few years a quite large number of elementary processes of the selective effect of laser irradiation of matter in various unit states have been proposed, discovered and successfully demonstrated: 1) atomic and molecular gases; 2) condensed medium; 3) heterogeneous medium (the boundary of the gas and their compensated media). However, the majority of the experiments have been performed with matter in the gas phase.

On excitation of the quantum states of the atoms and molecules, the following characteristics of them can be changed (see Fig 2):

- 1) Excitation of an atom or molecule decreases the height of the energy barrier (the activation of energy E_{act}) of the chemical reactions with participation of them and, consequently, it increases the reactivity (Fig 2.1).
- 2) The excited atom or molecule has lower ionization energy than the unexcited ones (Fig 2.2).
- 3) The excited molecule has lower dissociation energy than the unexcited molecule (Fig 2,3).
- 4) The molecule excited to the stable state can go into the unstable state with respect to the dissociation. This process is called predissociation (Fig 2, 4).
- 5) The excitation of the molecule can cause its spatial rearrangement called isomerization, as a result of which a molecule is formed by their chemical properties (Fig 2, 5).
- 6) On absorption of a photon by an atom or molecule as a result of the recoil effect, the direction of motion of the absorbing particle changes by a negligible, but completely observable amount, that is, the so-called photodeflection of the particle takes place (Fig 2, b).
- 7) The excited atom or molecule can have higher polarizability, different symmetry of the wave function, and so on, which theoretically must be exhibited in a change in the scattering cross sections of the excited particle on other particles, variation of the nature of its motion in the external field, and so on.

From this classification numerous possible photochemical and photophysical methods of laser separation of matter follow directly.

For an atomic gas it is possible to use three theoretically different processes (Fig 3, a): 1) photochemical reaction; 2) ionization; 3) variation in velocity or deflection of the trajectory of the selectively excited atoms. In the case of a molecular gas (Fig 3, b), in addition to the method used for atoms, two new methods are possible: the method of selective photodissociation of molecules and the method of photoisomerization of molecules.

Beginning in 1970 [10] at the Institute of Spectroscopy of the USSR Academy of Sciences we have developed primarily a photophysical approach in the selective effect of laser irradiation on matter, in particular, for the separation of isotopes. The photophysical approach differs significantly from the known photochemical approach. The idea of this statement is explained by Fig 4.

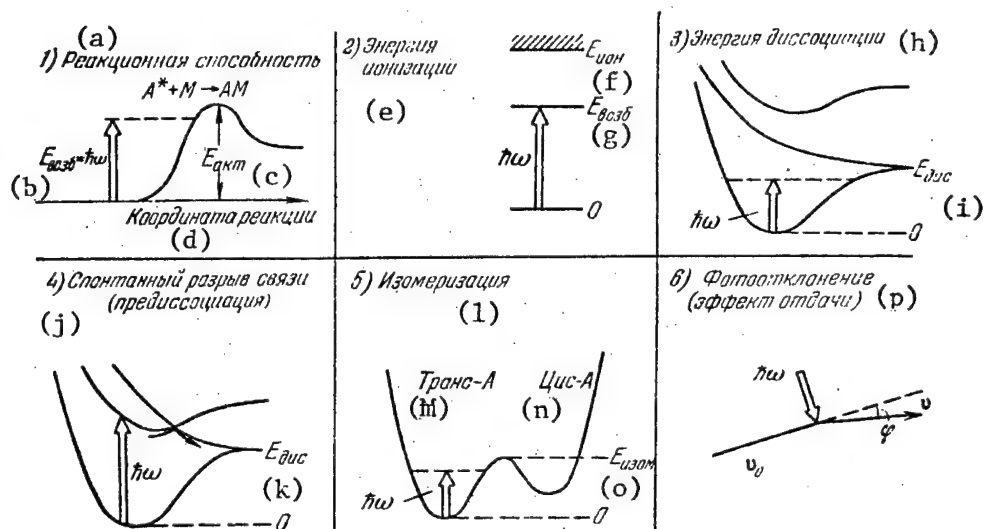


Figure 2. Properties of atoms and molecules that change on excitation by laser irradiation.

- 1) increase in reactivity; 2) decrease in ionization energy;
- 3) decrease in dissociation energy; 4) predissociation; 5) isomerization;
- 6) change in trajectory of motion.

Key:

- | | |
|---|------------------------------------|
| a. Reactivity $A^* + M \rightarrow AM$ | k. E_{diss} |
| b. E_{exc} | l. Isomerization |
| c. E_{act} | m. Trans-A |
| d. Reaction coordinate | n. Cis-A |
| e. Ionization energy | o. E_{isom} |
| f. E_{ion} | p. Photodeflection (recoil effect) |
| g. E_{exc} | |
| h. Dissociation energy | |
| i. E_{diss} | |
| j. Spontaneous breaking of the bond (predissociation) | |

Let us consider the atom (i)A with ground, excited energy states and a continuum corresponding to separation of the external electron from the atom, that is, ionization of the atom (see Fig 4, a). The atom of the other isotopic composition (n)A has somewhat shifted energy levels which permit monochromatic radiation excitation of the atoms of the selected isotope. Before the war, in 1933, successful experiments were run in Germany on the optical photochemical separation of mercury isotopes based on increasing the reaction rate of the excited mercury atoms (A^*) with oxygen (the acceptor R) [9]. However, the case of mercury atoms is exceptional as a result of the presence of metastable triplet states and intensive mercury lamps. Unfortunately, this photochemical approach could not be applied widely to other elements. In 1970, we proposed another approach based on the capacity of laser radiation to convert a significant part of the atoms to the given

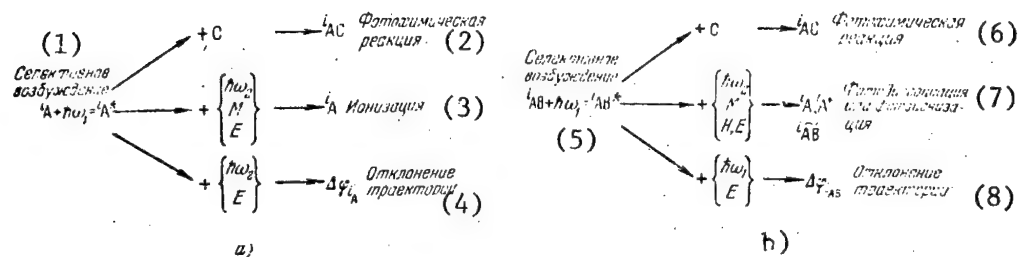


Figure 3. Basic methods of the selective effect of laser irradiation on atoms (a) and molecules (b)

Key:

- | | |
|---------------------------|---|
| 1. Selective excitation | 5. Selective excitation |
| 2. Photochemical reaction | 6. Photochemical reaction |
| 3. Ionization | 7. Photodissociation or photoionization |
| 4. Trajectory deflection | 8. Deflection of the trajectory |

excited state. It was proposed [10] that the photoionization of the selectively excited atoms be realized by additional laser irradiation until they return to the ground state or they transfer their excitation on collision with the atoms of another isotopic composition. This can always be done theoretically inasmuch as the probability of photoionization is proportional to the intensity of the additional irradiation. Thus, the process of selective photoionization, in contrast to the photochemical reaction does not require collisions with another particle and, consequently, it is entirely controlled by the laser irradiation.

An analogous situation is possible also for molecules. Let us consider a molecule with ground and excited electron states (stable and unstable) (see Fig 4, b). With the photochemical approach, the selectively excited molecule $(i)AB^*$ must theoretically enter into the chemical reaction on collision with another particle (acceptor R) at a reaction rate exceeding the reaction rate for the unexcited molecules. The processes of relaxation of excitation and mixing of excitation in the case of collisions of molecules of different isotopic composition compete with the photochemical reaction process. In 1970 we proposed [10] the realization of photodissociation of selectively excited molecules by auxiliary laser irradiation with a rate exceeding the rate of all harmful competing processes, and then chemical binding of the radicals formed as a result of photodissociation. Again, with this approach we fully control the process of selective excitation by laser irradiation of matter.

The selective processes in the condensed medium were investigated much less and turned out to be less prospective as a result of broadening of the spectral lines and normal temperatures and fast relaxation of the oscillatory excitation. This dictates defined rigid conditions for the experiments with respect to selective effects: 1) excitation of electron states relaxing

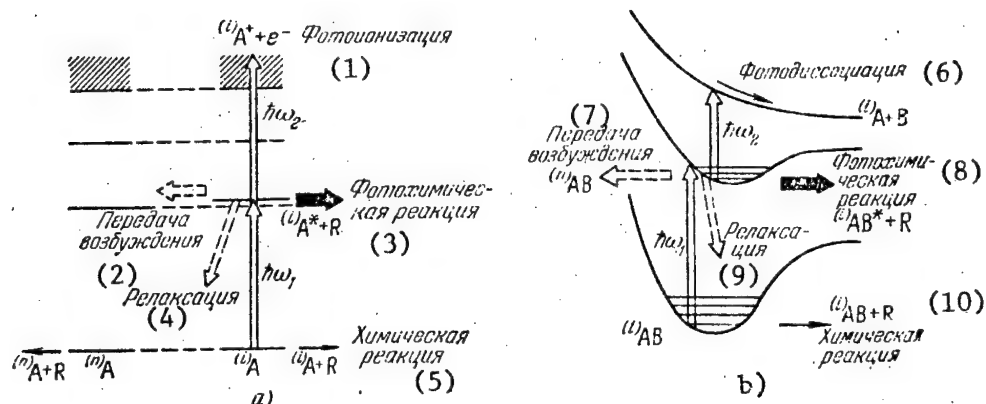


Figure 4. Universal processes of two-stage selective excitation of matter by laser irradiation

a) Selective two-stage photoionization of atoms; b) selective two-stage photodissociation of molecules and comparison of it with the photochemical processes

Key:

- | | |
|----------------------------|----------------------------|
| 1. Photoionization | 6. Photodissociation |
| 2. Excitation transmission | 7. Excitation transmission |
| 3. Photochemical reaction | 8. Photochemical reaction |
| 4. Relaxation | 9. Relaxation |
| 5. Chemical reaction | 10. Chemical reaction |

much more slowly than the oscillatory states; 2) the application of low temperatures at which the broadening of the spectral lines and the rate of V-T-relaxation decreases sharply; 3) the application of ultrashort pulses. There are a total of several examples of the isotopically selective photochemical processes in a condensed medium [11, 12], but obviously the case of the condensed medium has the greatest significance for realization of the selective photobiochemical processes.

In the case of the heterogeneous medium it is possible to realize the selective effect both on the particles in the gas phase and on the atoms and molecules on the surface of the condensed medium. In the first approach it is possible to use such processes as the photochemical reactions, photoadsorption [13] and condensation of excited atoms and molecules [14]. By the excitation of atoms or molecules on the surface of the condensed medium it is possible to achieve selective separation, photodesorption and evaporation of them. The selective separation of the atoms and molecules of defined variety adhering to the surface [15, 16], is a very important, but in practice most difficult to realize and little developed process. The selective separation of the electron or proton from the defined sections of the micromolecules can turn out to be highly important for direct decoding of the chemical-spatial structure of the biological molecules [17].

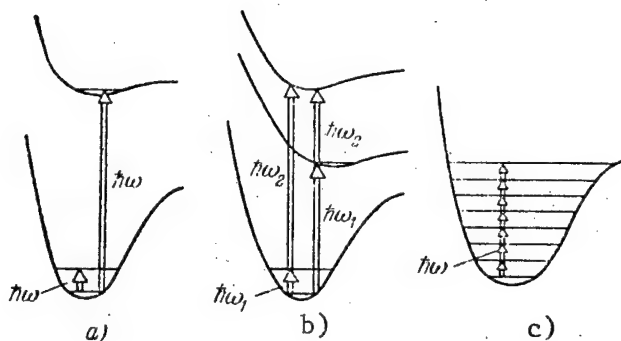


Figure 5. Types of selective photoexcitation of a molecule

- a) Single-stage excitation of the electron or oscillatory state;
- b) two-stage excitation of the electron state in terms of the intermediate oscillatory or electron state; c) multiphoton excitation by infrared radiation

4. Classification Methods

a) Type of Photoexcitation

Various types of selective photoexcitation of molecules are illustrated in Fig 5 in highly simplified form. The classical (prelaser) photochemical method is based on the single-stage excitation of the electron state of an atom or molecule. This type of excitation of the molecule has a very serious deficiency for selective photochemistry. The majority of molecules, especially multiatomic molecules, have comparatively broad structureless electron absorption bands at normal temperature. Therefore, according to this scheme, isotopically selective excitation of the majority of molecules is, for example, impossible. Only a limited number of simple, primarily bioatomic and triatomic molecules have narrow electron absorption lines which are suitable for selective excitation. On the other hand, the excitation of the electron state is advantageous as a result of the high quantum yield of the photochemical reaction.

The single-stage excitation of the oscillatory state of a molecule (photochemistry in the ground electron state) has a comparatively high excitation selectivity both for simple and for complex molecules. The basic deficiency of this method is a fast relaxation of the oscillatory excitation into heat and, consequently, low quantum yield of the subsequent photochemical process. In addition, this method can be used only for photochemical reactions with low activation energy.

The two-stage excitation of the electron state of the molecule through the intermediate oscillatory state by the joint effect of infrared and ultraviolet radiation (Fig 5, b) combines the advantages of the single-stage infrared

and ultraviolet excitation processes, eliminating their deficiencies [18]. In the two-stage method, by photoexcitation by a two-frequency (IR+UV) laser field, separation of the selective excitation functions is achieved where the molecule receives comparatively low energy (IR photon) and absorption of a quite high energy (UV photon) by the selectively excited molecule. This type of two-stage photoexcitation has simultaneously quite high selectivity and high quantum yield of the photochemical process. The advantages of the two-stage (IR+UV) excitation in the case of condensed media must be exhibited especially clearly, where the contradiction between the high selectivity and high quantum yield at normal temperatures become unresolvable.

The two-stage excitation of the molecules through the intermediate electron state (see Fig 5, b) is not so universal as the IR+UV excitation. Its only advantage over the single-stage excitation of the electron states is the possibility of the excitation of the states with defined properties and higher lying states without using the VUV-irradiation.

For the multiatomic molecules, the selective excitation of the higher lying oscillatory and even excited electron states is possible under the effect of only quite powerful IR radiation [19]. As a result of the multiple absorption of the IR photons of one frequency, the molecule receives energy comparable to the standard energy of the electron excitation (see Fig 5, b). Therefore it turns out to be possible simultaneously to realize selectivity of excitation sufficient even for separation of the isotopes and comparatively high quantum yield of the subsequent photochemical process. Here the separation of the functions of selective excitation and the subsequent gathering of large energy by the excited molecule in the two-frequency IR field is also possible [20] which insures an increase in selectivity of the process. A deficiency of the method of multiple absorption of the IR radiation is the applicability of it only to multiatomic molecules having very high density in the excited oscillatory levels in the ground electron states.

The last two approaches in selective photochemistry depicted in Figures 5, b, c are realizable only by using laser irradiation, for strong population of the intermediate quantum levels is required. This is theoretically impossible to realize efficiently in any way by using ordinary, incoherent light sources as a result of the low radiation temperature. The ordinary light sources are applicable only for the single-stage processes and then with much greater effectiveness for the electrons than for the oscillatory states.

In Table 1 a summary survey of the advantages and disadvantages of each of the mentioned methods of selective photoexcitation is presented. Of course, the selective excitation systems which are intermediate with respect to the investigated systems are entirely realizable. For example, it is possible by multistage excitation by a multifrequency IR field to achieve high oscillatory levels of even a simple molecule. Or, for example, by the two-frequency visible laser emission in the Raman type process it is possible

Table 1

Comparison of Various Methods of Selective Photoexcitation
of Molecules

Method	Advantages	Deficiency
1. Single-stage excitation:		
a) Electron state	1) High excitation energy 2) Small role of the thermal effects	1) Low selectivity for multi-atomic molecules
b) Oscillatory state	1) High selectivity	1) Low excitation energy 2) Loss of selectivity as a result of normal heating
2. Two-stage excitation of the electron state through intermediate:		
a) Oscillatory state	1) High excitation energy 2) High selectivity 3) Small role of thermal effects	
b) Electron state	1) High excitation energy 2) Small role of thermal effects 3) Flexibility of excitation of states with high energy	1) Low selectivity for multiatomic molecules
3. Multiphoton excitation of higher lying oscillatory levels	1) High excitation energy 2) High selectivity 3) Small role of thermal effects	1) Unacceptability for simple molecules

to excite oscillatory levels. Therefore very sharp boundaries can sometimes be realized between the different methods, and the investigated classification of methods, their advantages and deficiencies is to a certain degree provisional.

b) Type of Photoprocess

The excited molecule can participate in the subsequent photochemical process with respect to several different mechanisms. In the most general and simplified form they can be classified as follows: 1) photochemical reaction of the excited (electron or oscillatory) molecule with suitable acceptors; 2) photodissociation (or photopredissociation) of the excited molecule; 3) photoisomerization, that is, variation of the spatial structure of the

excited molecule. All of these types of photochemical conversions are well known in photochemistry (see, for example, [21]). However, from the point of view of achievement of high selectivity of the photochemical process and its universality, these mechanisms are far from equivalent. Each of them has its own advantages and disadvantages for selective photochemistry.

The first process (the participation of the excited molecules in the reaction) is potentially highly universal. Actually, any molecule has an excited electron state with increased reactivity which, using the appropriate scheme (see Fig 5), can be selectively excited by laser radiation. However, this process requires the selection of an appropriate acceptor which will enter into the reaction with the excited molecules with a higher rate than with the unexcited molecules. The rate of entry of the excited molecule and the reaction with the acceptor must essentially exceed the rate of transfer of the excitation during the collisions with molecules of an undesirable variety and also the excitation relaxation rate. Another fundamental requirement consists in reserving the selectivity of the photochemical reaction in the unavoidable successive secondary photochemical reaction. These are quite serious requirements which, as a rule, are very difficult to satisfy. It is sufficient to state that only quite recently it was possible to demonstrate the high degree of isotopic selectivity of the photochemical reaction [22] (electron-excited ICl molecule entered into the reaction with the $C_2H_2Br_2$ acceptor molecule). It is especially complicated to satisfy all of these requirements for the oscillatory excited molecules when the difference in the velocities of the excited and unexcited molecules is comparatively small.

The photodissociation of the molecules is just as universal a process as the photochemical reaction of the excited molecule. The photodissociation can be realized either by excitation of the unstable electron state (the repelling therm) of the molecule or within the limits of the ground electron state by strong oscillatory excitation. Until quite recently, photodissociation was known only through the excited electron state, and only the creation of power laser pulses of infrared radiation made it possible to realize the second possibility. These two methods of selective photodissociation of the molecules differed quite sharply from each other.

Each molecule has excited unstable electron states which are suitable for photodissociation of the molecules. Inasmuch as the dissociation of the molecule on the declining electron therm takes place extremely quickly (in a time on the order of 10^{-13} to 10^{-14} sec). Of course, relaxation and excitation transfer do not play a role for such a short time. Since the electron absorption band on the transition to the dissociation state is broad, the selectivity of the excitation can be insured only by means of the two-stage or multistage process (see Fig 5, b). Therefore the requirements on smallness of the loss of excitation as a result of relaxation and transfer of excitation pertain to the intermediate excited state. By selecting the intensity and the duration of the second stage ultraviolet radiation it is always possible to satisfy these requirements [18]. Since the

dissociation products are usually radicals, it is necessary to use the collector molecules of the radicals which chemically bind them without touching the initial molecules. The selection of these collectors of the dissociation products not causing significant loss of selectivity and the secondary photochemical processes is a simpler problem than in the case of the chemical reaction of the excited molecules.

Sometimes the electron-excited molecule dissociates not as a result of the repelling nature of the electron term, but as a result of the intersection of the stable term with the repelling one. In this case the dissociation caused by the photopredissociation takes place more slowly, for example, in the time 10^{-6} to 10^{-12} sec for different molecules and excited electron-oscillatory-rotational states. As a result of narrowness of the absorption lines on the transition to the predissociation state the high selectivity of the excitation can be insured by using the single-stage process of photoexcitation [23, 24]. This presents a new advantage for the method of photodissociation, it is true, at the price of loss of universality as a result of the limited number of molecules having the photopredissociation phenomenon.

The photodissociation in the ground electron state (see Fig 5,c) potentially even has advantages over the photodissociation through the excited electron states. First, it requires less expenditure of energy; secondly, it gives fewer energy radicals. However, in practice it is entirely impossible to realize this process with its advantages as a result of the absence of an appropriate method of photoexcitation of a molecule. We are talking only about the oscillatory transitions of the molecule, but, however, as a result of the nonequidistant nature of the successive oscillatory-rotational transitions for photoexcitation to the dissociation boundary would require the use of multifrequency IR laser radiation. Theoretically this is possible, but the modern label of tunable laser engineering still does not permit its realization. The situation was radically simplified after discovery [25, 26] of the phenomenon of collisionless dissociation of multiatomic molecules in a strong IR laser field. The rich structure of the oscillatory-rotational transitions of the multiatomic molecule permits absorption of a quite large number of IR photons if the laser field is sufficiently intense. Moreover, this process of photodissociation in the single-frequency strong IR field has selectivity which permits separation of the isotopes [19, 27]. Thus, the photodissociation in the ground electron state in a powerful IR field turns out to be a simpler process, but again at the price of some loss of universality (inapplicability to the simple diatomic and triatomic molecules). The remaining advantages and disadvantages are common for any photodissociation methods.

The photoisomerization of the molecule, just as the photodissociation, is a nonmolecular photochemical process which does not require collisions with other particles. This is the advantage of both approaches by comparison with the chemical reaction of the excited molecule for which collisions are needed with the mentioned deficiencies forced out (loss of excitation and selectivity). However, photoisomerization, in contrast to the first two

methods, does not require participation of any acceptors in general, and therefore for this method in practice no loss of selectivity occurs in the secondary photochemical processes. The only deficiency of this method consists in the quite limited number of molecules for which the phenomenon is possible. Since the final state of the phototransition of a molecule is stable, the selective photoisomerization in the case of a narrow absorption line can be realized by single-stage photoexcitation [28]. Otherwise it is possible to use the two-stage photoexcitation.

In Table II, a survey of the advantages and disadvantages of the investigated photochemical process is presented in summary form. The table is not complete, for we have also not investigated molecular processes such as photoionization, dissociative photoionization as a result of which charged particles are formed (electrons, positive and negative ions). Although the proposals are known with respect to the selective photoionization of molecules by the two-stage photoexcitation [29] and the first successful experiment has recently been realized [30], for selective photochemistry these processes hardly have any advantages by comparison with photodissociation. Their application will more be limited to the region of selective detection of the complex molecules and molecular bonds where, after selective excitation by the laser radiation theoretically it is important to obtain charged particles [17].

A more detailed study is made of the basic selective photophysical and photochemical processes as applied to the specific situation -- separation of the isotopes. Of course, the regions of application of them are much broader than the separation of the isotopes. Some of the applications are considered in the subsequent sections of the article.

5. Photophysical Methods of Separating Isotopes

The basic photophysical methods which are of interest for practice and actively developed in many laboratories are as follows: 1) selective stepped ionization of the atoms; 2) selective stepped photodissociation of the molecules by IR+UV-radiation; 3) photopredissociation of molecules; 4) multiphoton dissociation of molecules in a strong IR field. Each of these methods has been demonstrated under laboratory conditions. It has its own defined advantages and disadvantages, and is in the stage of either proof of the expediency of realization on pilot units (methods 2) and 3)) or already being realized in pilot units (method 1) and 4)).

a) Selective Multistage Photoionization

The selective photoionization of atoms is the most universal photophysical method of selective separation of matter, in particular, isotopes, on the atomic level. A common characteristic of all of the selective ionization schemes is the sequence of the process: 1) isotopically selective excitation; 2) ionization of the excited atoms. In Fig 6 we have some of the schemes for selective ionization of atoms which are of interest for later separation

Table II

Comparison of Real Photochemical Molecular Processes

Process	Advantages	Deficiency
1. Chemical reaction of a molecule in the excited state	1) Universality	1) Special selection of the appropriate acceptor 2) Loss of selectivity in the secondary photochemical process 3) Loss of excitation as a result of relaxation 4) Loss of selectivity as a result of excitation transmission
2. Photodissociation (photopredissociation)	1) Universality (absent for photopredissociation) 2) Small excitation losses as a result of relaxation 3) Absence of loss of selectivity as a result of excitation transmission	1) Necessity for two-stage (multistage) photoexcitation (can be absent for photopredissociation) 2) Special selection of the acceptor for collecting the radicals 3) Loss of selectivity in the secondary photochemical processes
3. Photoisomerization	1) Small losses of selectivity as a result of excitation transmission 2) No necessity for using the acceptor 3) Absence of loss of selectivity in the secondary photochemical processes	1) Nonuniversality

of isotopes. The two-stage photoionization scheme is the simplest [10, 18, 31]. The three-stage scheme can be used, let us say, for atoms with high ionization potential. The photoionization cross section can be enlarged by tuning the radiation frequency in the last stage to the transition to the autoionization state (spontaneous [32] or induced by an electric field [33]) (see Fig 6, c). Finally, the highly excited Rydberg states of the atoms can be ionized either by infrared radiation [34] or by a pulsed electric field [33] (see Fig 6, d. e).

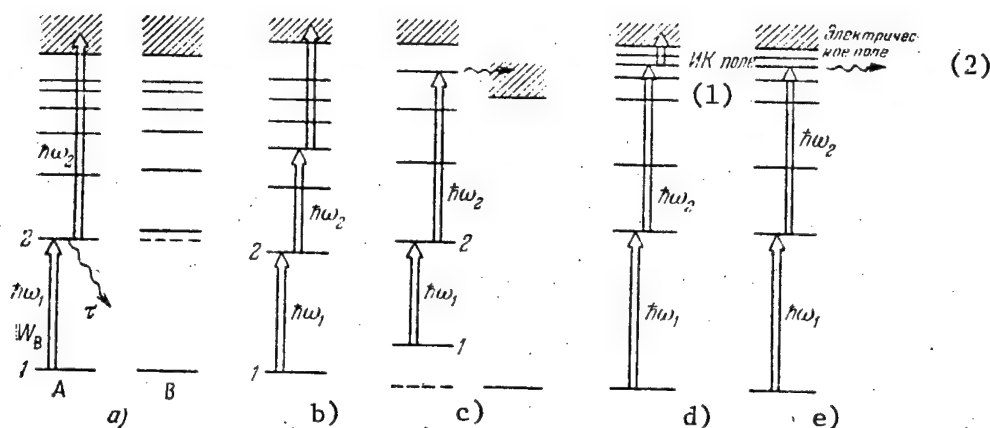


Figure 6. Schematic of the selective stepped photoionization of atoms by laser irradiation.

- a) two-stepped photoionization; b) three-stepped photoionization; c) two-stepped photoionization through the autoionization state; d) two-stepped selective excitation of the Rydberg state and photoionization of it by infrared laser emission; e) two-stepped selective excitation of the Rydberg state and its ionization by an electric field.

Key:

1. Infrared field
2. Electric field

The first successful experiment with respect to the selective two-stage ionization of atoms (in the example of rubidium atoms) was realized at the beginning of 1971 at the Spectroscopy Institute of the USSR Academy of Sciences [18, 31].

All of the indicated schemes have been experimentally tested for isotopically selective ionization. A detailed discussion of these schemes, their advantages and disadvantages is beyond the scope of this article. The interested reader can find all of this information in a special survey [35] or in the corresponding, more compact sections of surveys [4-7]. As an example let us present only the general requirements which must be satisfied by the scheme for selective ionization on separation of the isotopes on a practical scale:

1) All of the atoms in the unexcited beam must be in the ground state, and the ions must be absent. If the atoms of the selected isotope are distributed over several levels or sublevels, then the multifrequency radiation is required for excitation of the atoms from all sublevels in order completely to extract the selected isotopes from the mixture. Any thermal ions existing in an atomic pair must be eliminated before laser excitation.

2) The laser emission must cause selective photoionization of each selected isotope. This imposes defined requirements on the power of the exciting

and ionizing radiation which essentially depends on the cross sections of the excitation and ionization processes.

3) The intensity of the laser emission must be used in practice completely for excitation and photoionization of the selected isotope. This imposes defined requirements on the configuration of the atomic flux and laser beams and atomic density in the flux.

4) Transmission of the excitation or charge between the separated isotopes should not occur. This condition essentially eliminates the admissible density of the atoms.

The separation of uranium isotopes is attracting the greatest attention. Results have been published from the research programs of the Avco Everett Research Laboratory at the Lawrence Livermore Laboratory. In 1974, at the 8th International Conference on Quantum Electronics, the first experiments of the Livermore Laboratory were presented [36]. In this experiment for the excitation of U^{235} atoms, a continuous-action dye laser was used, and the ultraviolet radiation of a mercury lamp photoionized the excited atoms. The coefficient of selectivity of the separation reached 10^2 . In 1975 this laboratory reported the results of the experiments with respect to the two-stage ionization of uranium atoms by the irradiation of the line of the xenon and krypton ion lasers [37]. The yield of U^{235} ions in this experiment corresponded to an output capacity of 2×10^{-3} grams/hr which exceeded the yield in the first experiment by 10^7 times.

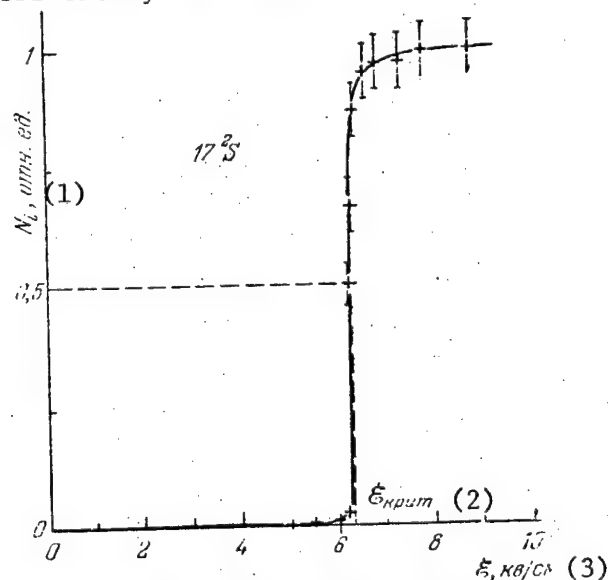


Figure 7. Ion signal as a function of the intensity of a pulse of a constant electric field ionizing the Na atom from the $17^2S_{4/2}$ state.

Key:

- | | |
|---------------------------|----------|
| 1. N_i , relative units | 3. kv/cm |
| 2. E_{crit} | |

A research and development program on an industrial scale is being carried out by the joint efforts of the Avco Everett Research Laboratory and the Exxon Nuclear Company. Some of the results of this work obtained, according to the statement of the authors, in the early stage of the work in 1971, were presented [38] in 1975. In the experiment in which the frequency of the exciting pulsed dye laser was scanned in a sufficiently broad range of U235 and U238 transitions and the pulsed N₂-laser photoionized the excited uranium atoms in a natural mixture, selectivity of separation of K (235/238) of approximately 140 was achieved.

In addition to the process of separation of the uranium isotopes imposing the above-formulated quite rigid conditions, studies are being made in the laboratory of the methods of selective ionization of other isotopes such as K, Ca, Rb, rare earth elements, and transuranium elements with much smaller potential output capacity of the devices. In these cases the effective ionization of the excited atoms at moderate medium power of the ionizing radiation is a serious problem. The ionization schemes depicted in Fig 6, a-c are disadvantageous, and the greatest attention is being given to the ionization schemes for the highly excited atoms depicted in Fig 6, d, e (see the survey [35]).

From the point of view of ease of ionization, the highly excited ions are of very great interest for separation of the isotopes [33, 35]. The first successful experiment with respect to increasing the photoionization cross section as a result of the electric field induced autoionization of the Rydberg state was performed in reference [39] on sodium atoms. A detailed discussion of the autoionization of the highly excited states of the Na atoms was made in reference [40-42]. The quantum state with the principal quantum number n falls in the continuum with an electric field intensity (in atomic units):

$$E_{qp} \geq (16n^4)^{-1} \quad (1)$$

Key:

1. cr

(1 atomic unit = 5×10^9 pulse/cm). Fig 7 shows the experimental dependence of the ion yield on the electric field intensity for the Na atoms selectively excited in the 17²S state. With an electric field pulse intensity of a total of a few kv/cm, complete ionization of the atom is achieved in the highly excited state.¹ Thus, use of the electric field is an effective and simple method of ionization of highly excited atoms.

¹Let us note that the study of the highly excited atoms is a very actively investigated area of atomic physics [43], the discussion of which goes beyond the scope of this article.

b) Selective Two-Stage (IR+UV) Photodissociation

The process of selective two-stage photodissociation of the molecules is realized if the excitation of the molecules shifts the continuous photoabsorption band which causes photodissociation of the molecule. Then, selecting the frequency ω_2 of the additional laser emission in the shift region where the ratio of the absorption coefficients of the excited and unexcited molecules is maximal, it is possible to realize the photodissociation of the molecules excited selectively by the laser emission with a frequency ω_1 through the excited unstable electron state. The method of selecting two-stage photodissociation through the intermediate oscillatory state under the effect of the infrared and ultraviolet radiation is in practice of greatest interest (Fig 8, a).

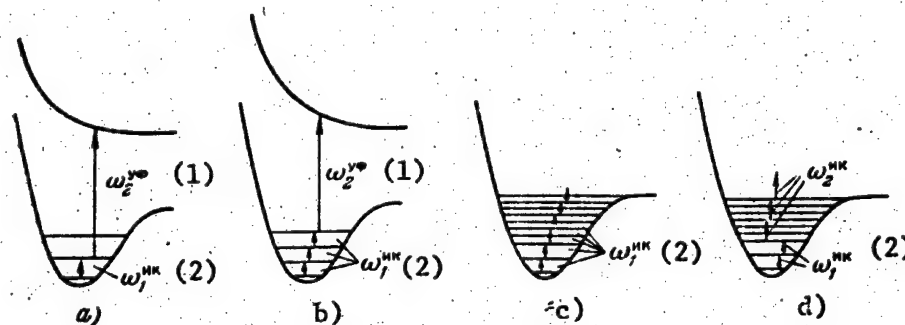


Figure 8. Schematics of the selective multistage photodissociation of molecules by laser emission through the excited electron state (a, b) and the ground electron state (c, d)

a) two-stage IR+UV photodissociation; b) multistage selective excitation of high oscillatory levels and their photodissociation by UV radiation; c) multiphoton selective excitation and association by a single-frequency intense IR field; d) multiphoton selective excitation of the oscillatory levels by the resonance IR field and their multiphoton dissociation by nonresonance intense IR emission

Key:

1. UV
2. IR
3. IR

The process of two-stage photodissociation of the molecules is more complex than the process of the two-stage photoionization of atoms as a result of the following effects which influence the selectivity and the process rate [18]: 1) the thermal nonselective excitation of oscillatory levels; 2) the blurring of the edge of the electron photoabsorption band of the molecule; 3) the effect of the "bottleneck" as a result of the rotational structure of the oscillatory levels. These two effects limit the selectivity of the dissociation, and the third effect limits the absorption rate of the IR radiation by the molecule from above [44] and, consequently,

the rate of the process of two-stage photodissociation of the molecules in the gas. A detailed discussion on these effects is presented in the surveys [4, 7] and the original articles. Here we only know that the influence of the first effects can be significantly reduced by using the selective excitation of the higher-lying oscillatory levels (Fig 8, b). This can be realized by several procedures: 1) direct excitation of the high levels by laser emission on the frequency of the overtone transitions as was done, for example, in reference [45] for the HCl molecule; 2) successive stepped excitation of the higher levels by multifrequency IR emission; 3) resonance excitation of the higher levels of the multiatomic molecule by an IR field pulse as a result of multiple absorption of the IR photon by the molecule as was demonstrated for the SF₆ molecules [20, 27] and OsO₄ molecules [46] and many others.

The first successful experiments with respect to the separation of isotopes by the method of two-stepped selective photodissociation were described in references [47, 48]. These experiments were performed with the NH₃¹⁴ and the NH₃¹⁵ molecules, for, first of all, they can be excited selectively by the emission of the CO₂-laser and, secondly, for ammonia, the IR and UV absorption spectra and photochemical decomposition have been well investigated. The enrichment coefficient for the final product of N₂ varied from 2.5 to 6. These results were later confirmed by the Japanese researchers [49]. In reference [50] there is a report on the separation of the boron isotopes B¹⁰ and B¹¹ by the method of two-stage selective photodissociation of the BCl₃ molecule on a similar device (CO₂-laser and incoherent source of UV radiation in the 2000 Angstrom range). In these experiments, only 10% enrichment of the mixture with the light boron isotope was obtained which is comparable to the standard value of the kinetic isotopic effect.

The universality of the process of the two-stage photodissociation of the molecule by the joint effect of the IR and UV emission is limited by the molecule having unstable excited electron state with an energy of less than 4 to 5 eV which can be excited by the radiation in the admissible ultra-violet range ($\lambda_2 > 2000$ Angstroms). From this point of view the process of multiphoton dissociation of the multiatomic molecules by a strong IR field as a result of the oscillatory conditions within the limits of the ground electron state is more universal. However, since the method of two-stage IR+UV-dissociation is theoretically applicable to a number of molecules with heavy isotopic atoms which are of practical interest, it is being developed actively at a number of laboratories [3, 5, 7].

c) Single-Stage Selective Photopredissociation

For separation of the isotopes by photopredissociation, the excited state of the molecule is required which exhibits a permissible isotopic shift and decays primarily as a result of dissociation, the dissociation products of which can be eliminated from the initial material by a simple method. This method is not so common as the two-stage photoprocesses. In addition, for the majority of molecules, there are insufficient spectral and photochemical data to know in advance about the satisfaction of these requirements.

The total predissociation was investigated in the greatest detail for the formaldehyde molecule primarily by B. Muhr, et al. From near the beginning of the first excited singlet state the H_2CO dissociates with high quantum yield into H_2 and CO , that is, absorption of only one photon leads to chemically stable dissociation products. The separation of the light hydrogen and deuterium in mixtures with equal H_2CO and D_2CO content was demonstrated in references [23, 51-53]. Enrichment coefficients K (D/H) on the order of 9 were achieved which were limited by the selectivity of the laser excitation [52]. An experiment was performed [54] with respect to separation of the hydrogen isotopes in the natural mixture of H_2CO and HDCO , in which the absorption coefficient K (D/H) reached 14 on irradiation of the formaldehyde by a continuous He-Cd laser on 325.03 nm. On irradiation in the mixture of $\text{H}_2^{12}\text{CO}:\text{H}_2^{13}\text{CO}=1:10$, 80-fold enrichment of the CO with the C^{12} isotope was obtained [55]. At the present time spectroscopic and photochemical studies are being performed [56], which should lead to more complete understanding of the photo processes in formaldehyde and realization of practical systems for separation of C^{13} , O^{18} and O^{17} isotopes.

An entire series of experiments have been performed with respect to the selective photopredissociations of other molecules. Leone and Muhr [57] excited Br_2 into the predissociation $^3\Pi_{o+\pi}$ -state and avoided the set of potential mixing processes by the fact that the infrared chemiluminescence of the HBr molecules formed in the oscillatory-excited states during the course of the reaction of the Br atom with HCl was observed. The enrichment coefficient K ($\text{Br}^{81}/\text{Br}^{79}$) was about 5. The authors of references [58, 59] converted the ortho-iodine molecule to the para-iodine as a result of selective predissociation of the molecules of the ortho- I_2 on excitation by the 514.5 nm line of an argon laser, and they obtained an enrichment coefficient K (para/ortho) on the order of 2 to 4. This process can be used for separation of iodine isotopes. Hochstrasser and King [11] and Karl and Innes [60] independently obtained high enrichment coefficients of the nitrogen and carbon isotopes in irradiation of the molecules of tetrazine with a natural content of the isotopes in the low-molecular condensed medium [11] in the gas phase [60]. They proved that the predissociation is described by the reaction: $s\text{-tetrazine} \rightarrow \text{N}_2 + 2\text{HCN}$.

The photopredissociation promises to become a practical method of separating isotopes. The work with H_2CO and, possibly, with $s\text{-tetrazine}$ can lead to economically vital methods of enrichment of the C^{13} , C^{14} , O^{17} and O^{18} isotopes. Although this method is not so common as the two-stage methods, it can be more practical in situations where it is applicable [7].

In spite of the significant simplicity of the photopredissociation approach, it still has not been brought to the development of "pilot" units even for one of the mentioned isotopes. Probably, this is connected with the limited energetics of the narrow-band tunable lasers in the UV band. The invention of excimer lasers with high efficiency can sharply accelerate the advancement of this method in practice.

d) Multiphoton Dissociation of Molecules

All of the above-investigated methods of laser separation of isotopes are based on the excitation of the electron states of the atoms and molecules by visible or ultraviolet radiation. The method of separating the isotopes discussed below is entirely different from them, for it uses only intense IR laser emission for direct excitation of very high oscillatory levels in the ground electron state (Fig 8, b-d). The method is based on the isotopically selective dissociation of the multiatomic molecules (BCl_3 [19], SF_6 [27], OsO_4 [46], and so on) by intense CO_2 -laser pulses. This effect was discovered in 1974 at the Institute of Spectroscopy of the USSR Academy of Sciences [19]. Its discovery was a logical and natural result of our systematic work with respect to isotopically selective dissociation of molecules by laser emissions. The discovery of this effect was preceded by several experiments [25, 26, 61-63] with respect to the interactions of powerful pulses of infrared radiation with molecular gases. A detailed discussion of these early papers was carried out in the survey [8] and briefly in references [64].

Let us also note the work of Askar'yan [65], Bunkin, et al. [66] in which a theoretical study was made of the pumping of the oscillations and the dissociation of the diatomic molecule in a strong laser field. Although the multiphoton dissociation of the diatomic molecule requires exceptionally high intensities (10^{11} to 10^{12} watts/cm²) and it has not been observed experimentally up to now, the early papers [65, 66] contained the idea of strong oscillatory excitation and dissociation of a molecule within the limits of the ground electron state. This constitutes a defined similarity with the discussed phenomenon of strong excitation and dissociation of multiatomic molecules in the resonance IR field of moderate intensity (10^5 to 10^7 watts/cm²).

The essence of the effect consists in the following. When the radiation frequency of the CO_2 -laser is tuned to the oscillatory band of the molecule, the isotopic shift of which is comparable to or even greater than the width of the Q-branch of the oscillatory band, with an intensity on the order of 10^7 to 10^9 watts/cm², irreversible dissociation of the irradiated isotopic molecule takes place. This is reflected in a change in the isotopic composition (enrichment) of the nondissociated molecules and the molecules formed as a result of dissociation. In the first experiments [27], the coefficient of enrichment of the residual SF_6 gas by the S^{34} isotope reached values above 3000.

The chemical composition of certain pure gases (BCl_3 , OsO_4 , and so on) remained invariant even under the effect of quite intense radiation in which visible luminescence occurs, that is, dissociation of the molecules definitely takes place. The studies demonstrated that this was caused by the inverse reaction, that is, recombination of the dissociation products with the formation of initial molecules. If acceptor molecules are added to the gas which enter into the reaction with the dissociation products to recombination of them, irreversible isotopically selective dissociation of the initial molecules takes place where the powerful infrared radiation acts on the gas

mixture ($\text{BCl}_3 + \text{O}_2$ [19, 67], $\text{OsO}_4 + \text{C}_2\text{H}_4$ [46], and so on). In this more general sense, the dissociation under the effect of powerful IR emission is typical of all of the multiatomic molecules, and it is not an exception for certain molecules.

At the present time the researchers have obtained a great deal of information on the separation of isotopes by dissociation by the method of multiphoton absorption of infrared radiation for a large number of multiatomic molecules ($\text{B}^{(i)}\text{Cl}_3$ [19, 67, 68], $\text{S}^{(i)}\text{F}_6$ [27, 69, 70], $\text{Os}^{(i)}\text{O}_4$ [46], $\text{C}^{(i)}\text{Cl}^{(j)}_4$ [71, 72], $\text{Si}^{(i)}\text{F}_4$ [68], $\text{C}^{(i)}_2\text{F}_2\text{Cl}_2$ [68], $\text{CH}^{(i)}_3\text{NO}_2$ [73], $\text{Mo}^{(i)}\text{F}_6$ [74], $\text{Mo}^{(i)}\text{F}_6$ [74], $\text{H}^{(i)}_2\text{Cl}_2\text{C}_2$ [75], $\text{H}^{(i)}_2\text{CO}$ [76] and so on). The process of dissociation of the SF_6 molecules was investigated most carefully and comprehensively [69, 77]. This research offered the possibility of understanding the nature and the basic characteristics of both the process of selective dissociation and the process of separation of isotopes by this method. A detailed description of the method of multiphoton infrared laser photochemistry was presented in a special survey [8]. Here there is a brief discussion only of some of the most important aspects of this method.

The multiatomic molecule can absorb a large amount of energy (3 to 5 IR photons) in the IR field of comparatively moderate intensity (about 10^5 to 10^6 watts/cm²) as a result of the "soft" condensation of the oscillatory anharmonism on the lower transitions. The threshold intensity (or, more precisely, the threshold density of the energy for laser pulses with a duration of less than 10^{-6} sec) and the dissociation obviously is connected with the saturation of the oscillatory transitions lying in the oscillatory quasicontinuum which is characteristic of the multiatomic molecules. In very simplified form this explanation of the dissociation of the multiatomic molecules by a resonance IR field is illustrated by Fig 9. The existence of the mechanism of "soft" condensation of the anharmonism on the lower oscillatory transitions was proved by the successful experiments of [20] with respect to the dissociation of the SF_6 molecule and the two-frequency IR field [Fig 8, d). The IR field of comparatively low intensity on a frequency ω_1 selectively excites the molecules and converts them to the states on the lower boundary of the oscillatory quasicontinuum. The frequency ω_1 is in resonance with the molecular oscillation ν_3 . The IR field at a frequency ω_2 is adjusted with respect to ω_1 and serves for excitation of the molecules on the junctions in the oscillatory quasicontinuum to the dissociation method.

The soft concentration of anharmonism can be insured as a result of the application of the rotational energy of the molecules during the oscillatory transitions in the P and R branches [78] or as a result of the anharmonic splitting of the degenerate oscillatory levels of the symmetric multiatomic molecule [79,80]. The dissociation in the two-frequency IR field permits separation of the functions of selective excitation and dissociation between the two fields with different frequencies. In this case, an increase in selectivity of the dissociation is achieved, for the nonresonance strong field does not cause broadening of the lower resonance transitions

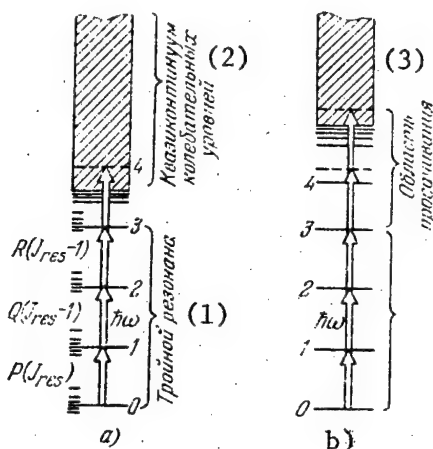


Figure 9. Explanation of the mechanism of dissociation of the multiatomic molecule in a strong IR field

a) Selective step excitation as a result of triple oscillatory-rotational resonance and successive excitation of molecules in the "oscillatory quasicontinuum"; b) selective excitation as a result of triple resonance with subsequent "infiltration" into the "oscillatory quasicontinuum."

Key:

1. Triple resonance
2. Quasicontinuum of oscillatory level
3. Infiltration region

as a result of the dynamic Stark effect and, on the other hand, for dissociation of the selectively excited molecules it is possible to use a strong field with quite coarse tuning of the frequency. In the first experiments with respect to dissociation of the SF_6 molecule in the two-frequency IR field, it was noted [20] that the dissociation rate maintains the dependence on the frequency ω_2 of the dissociating radiation. This relation is much more diffuse by comparison with the sharp dependence on frequency ω_1 of the exciting field. This indicates that the absorption on the transitions in the oscillatory quasicontinuum has broad peaks which are shifted to the red side (for SF_6) near the frequencies of the basic oscillations. Thus, for fine tuning of the frequency ω_1 to the frequency corresponding to the maximum selectivity of the dissociation and coarse tuning of the frequency ω_2 to the frequency corresponding to the minimum threshold intensity of the dissociation, it is possible to realize the optimal mode of isotopic dissociation of a multiatomic molecule in the nonfocused beams of the two-frequency infrared radiation [81].

This method appears today to be the most prospective for separation of isotopes of heavy elements by infrared radiation [8]. Recently, in references [81, 82] the two-frequency method was used to obtain absorption of the Os isotopes by the dissociation of the OsO_4 molecules with natural isotopic composition. An enrichment coefficient $K \approx 1.6$ was achieved,

at the same time as for dissociation of the molecule by the single frequency strong IR field, no enrichment was observed.

The multiphoton excitation of the oscillatory level is opening up new possibilities for the isotopically selective excitation in the absence of an isotopic shift in the linear IR absorption [73]. In Fig 10, a, the linear absorption spectrum of the $\text{CH}_3\text{N}^{14}\text{O}_2$ and $\text{CH}_3\text{N}^{15}\text{O}_2$ molecules in the region of 900 to 1100 cm^{-1} (the ν_7 and ν_{13} bands) with resolution of 0.5 cm^{-1} is illustrated in Fig 10, a. The isotopic shift for the ν_{13} band is absent within the limits of the experimental accuracy. In an intense IR field (a power of more than 10^7 watts/ cm^2), the absorption spectrum of both molecules varies differently. This is equivalent to the manifestation of the isotopic shift by ν_{13} of order 5 cm^{-1} (Fig 10, b). This effect was used to separate the nitrogen isotopes in a mixture of isotopic molecules of nitromethane.

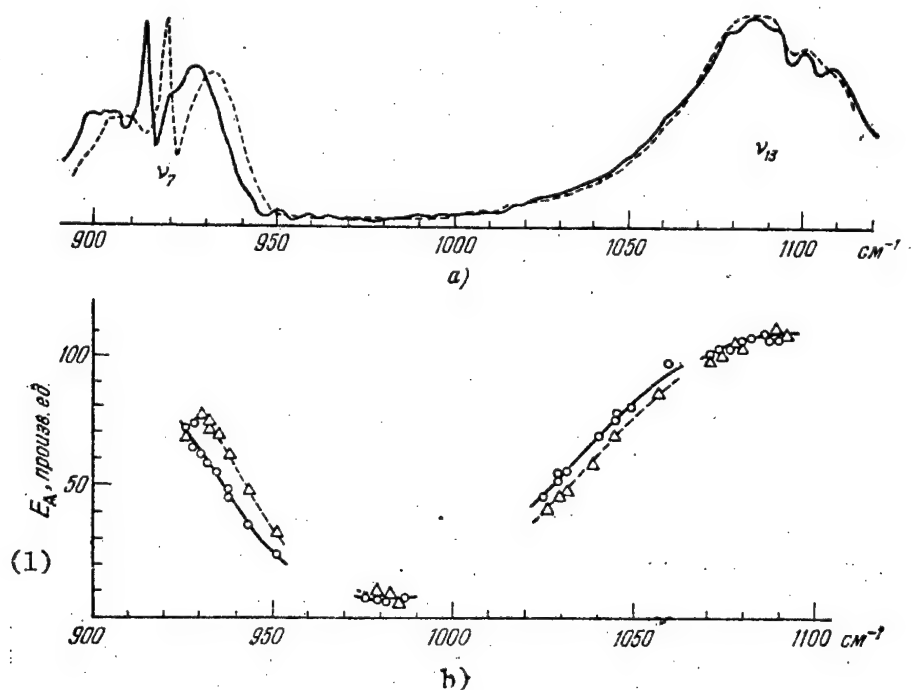


Figure 10. Isotopic effect for the ν_7 and ν_{13} bands of nitromethane. Solid curves -- for $\text{CH}_3\text{N}^{15}\text{O}_2$, dashed curves, for $\text{CH}_3\text{N}^{14}\text{O}_2$.

a) Linear absorption spectrum, pressure 20 torr; b) multiphoton absorption spectrum with a power of 10^9 watts/ cm^2 , pressure 2 torr [73].

Key:

1. E_A , undefined units

Let us note that far from all of the laser methods which have been successfully realized on a laboratory scale on separation of isotopes in indicator or even gravimetric amounts are prospective for the separation of isotopes on the scale of industrial production. The method which is potentially suitable for industrial use must have at least the following characteristics:

- 1) The possibility of the generation of laser emission required for the method with medium power level in the range from 1 kilowatt to 1 megawatt (depending on the required output capacity);
- 2) Simplicity and economy of the laser equipment in manufacture, operation, and maintenance.

These two requirements essentially limit the number of methods realizable on an industrial scale with lasers known to the present time.

The availability and cheapness of powerful IR radiation of molecular lasers and the relative simplicity of the method of multiphoton dissociation by the IR field makes this method the most available for realization on pilot units. The first experiments [83] with respect to the separation of isotopes in the field of a pulsed CO_2 -laser with high average power (to 500 watts) and high repetition frequency of the pulses demonstrated that under these conditions comparatively high isotopic selectivity of the dissociation is maintained. Fig 11 shows the experimental dependence of the isotopic selectivity of dissociation of the SF_6 molecules (by the mass analysis of the dissociation products SOF_2) on the repetition frequency of the pulses of the CO_2 -laser with an identical total number of pulses. These results uniquely indicate the possibility of creating a sufficiently high-output unit for separation of isotopes using the CO_2 -laser.

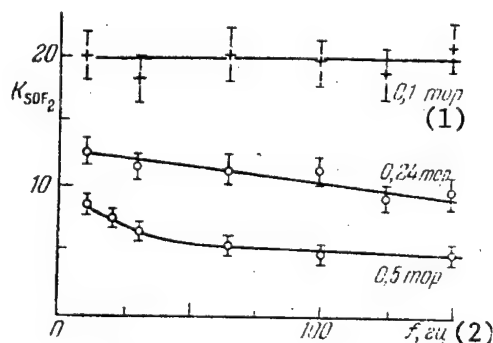


Figure 11. Separation coefficient of the isotopes in the products (SOF_2) of dissociation of the molecule of SF_6 ($\text{S}^{32}/\text{S}^{34}$) as a function of the repetition frequency of the f-pulses TEA of the CO_2 -laser for different pressures (0.1, 0.24 and 0.5 torr) with a fixed total number of pulses $N=1000$ [83].

Key:

1. torr
2. hertz

The simplicity and the technological nature of the described method of laser separation of isotopes must make it possible within a quite short period of time to begin its introduction in industry [83]. If we begin with the parameters of the process already achieved under laboratory conditions, then with an average power of the pulse CO₂-laser of 1 kilowatt (pulses with an energy of 10 joules and a repetition frequency of 100 hertz) with 10% use of the radiation, it would be possible to obtain approximately 0.3 grams/hour of the S³⁴ isotope enriched by 80%. The expected cost of the enriched stable isotopes of C¹³, N¹⁵, O¹⁷, O¹⁸, S³⁴ on the experimental devices must be 10 times less than the existing cost.

In conclusion, let us give attention to the prospects for the use of the method for the large-scale production of the isotopes. We have in mind the separation of isotopes required by the atomic industry -- the production of the monoisotopic construction materials, enrichment of the nuclear fuel and the production of heavy water for reactors [3, 4].

As an example let us consider the possibility of obtaining monoisotopic materials with low captured cross section of the neutrons, in particular, separation of the titanium isotopes [3]. The Ti⁵⁰ isotope (natural content 5.3%) has exceptionally low captured cross section of the slow neutrons (0.14 bn). Its various alloys have superior mechanical properties at high temperatures and exhibit very good resistance to corrosion. It could be used instead of zirconium for the shell of the elements of the nuclear reactor. It is already possible now completely definitely to predict the probability of the effective and economical processes of the separation of the titanium isotopes using the CO₂-laser and the TiCl₄ molecule having an overtone oscillatory band in the generation range of the CO₂-laser with large isotopic shift. For dissociation of one TiCl₄ molecule, about 10 ev of radiation of the CO₂-laser is required, and considering, for example, the 10% efficiency of the use of the radiation and the 10% efficiency of the laser, about 1 kev of electric power is required for the extraction of 1 Ti⁵⁰ atom, which corresponds to the expenditures of electric power of about 500 kilowatt-hours per kg of Ti⁵⁰. Inasmuch as the TiCl₄ is an intermediate product of mass production in nonferrous metallurgy, and its vapor pressure permits realization of the process at room temperature, it is possible to expect that the cost of enrichment of the titanium isotopes will be lower or of the same order as the cost of obtaining the initial products [3].

6. Photochemical Methods of Separation of Isotopes

At the present time the possibilities of the photochemical separation of the isotopes on excitation of both the electron states of the atoms and molecules and the oscillatory levels of the molecules have been successfully demonstrated. However, in spite of the significant optimism of the early papers, the actual progress has turned out to be much less impressive [22] than when using the above-investigated photophysical methods.

a) Electron Photochemistry

The chemical reactions of the electron-excited atoms and molecules were the subject of active research for many years, primarily before the creation of the laser. The photochemical separation of mercury isotopes was successfully demonstrated on excitation by the resonance line of 253.7 nm and when using a large number of different reagents [9, 84, 85]. For example, Pertel and Gunning [84] were able to enrich the Hg^{202} from the 30% natural content to 85% in mixtures with Hg, H_2O and butadiene. The kinetics of the photochemical reactions of Hg turned out to be so complicated that even the intense work by Gunning, et al. (see the survey of these papers in [86]) did not reveal the complete picture of the process. Hardeck, et al. performed successful experiments [87, 88] with respect to the separation of isotopes on excitation by the atomic resonant tube: the $\text{N}^{(1)}\text{O}$ molecule, by a tube based on Br atoms and the $\text{C}^{(1)}\text{O}$ by the tube based on I atoms. The absorption coefficient was on the order of 4 to 6.

Obviously, the laser sources have many advantages over incoherent sources for optical separation of isotopes. The broad frequency tuning and high limiting resolution permit comparatively free selection of the absorption lines in the visible, ultraviolet and possibly, vacuum ultraviolet regions, and they permit the highest selectivity to be obtained.

Several successful schemes for laser photochemical separation have been reported recently, primarily, by Zare, et al. The most interesting results were obtained in the experiments with respect to photochemical separation of Cl^{35} and Cl^{37} isotopes by selective excitation of the ICl^{37} molecules by the radiation of the continuous dye laser [39]. The laser emission excited only the ICl^{37} molecules to the state below the predissociation limit. The excited molecules participated in two types of reactions. In one case the ICl^{37} molecules reacted with the trans-ClHC=CHCl , forming the cis-ClHC=CHCl enriched by 10% by the Cl^{37} isotope. In the other case they reacted with the 1,2-dibromethylene, forming trans-IClC=CHCl enriched by 50% by the Cl^{37} isotope. The much higher enrichments in this scheme at a pressure of mixture of 7.5 torr were reported by Zare in the summer of 1976 [90]. When using a dye laser with high average power Schafer succeeded in successfully improving these results [91]. At the present time these results are most prospective in the isotopically selective electron photochemistry.

Another successful experiment for a diatomic halogen is described in references [59, 92]. The molecules of ortho- I_2 mixed with 2-hexene were excited by the 514.5 nm line of a continuous argon laser. The excited molecules of ortho- I_2 react with 2-hexene, and the unexcited molecules of para- I_2 do not enter into the reaction. The selective photochemical reaction of the molecules of ortho- I_2 studied in references [59, 92] is a repetition on a new level of experimentation of prelaser selective photochemistry [93], and it can be used directly for separation of stable and radioactive iodine isotopes.

In experiments [94], by selective excitation of the Cl_2CS molecules mixed with diethoxyethylene, enrichment of the Cl isotopes was achieved. The mass spectrometric analysis of the residual Cl_2CS molecules after irradiation either by an argon laser or by a dye laser demonstrated that the Cl^{35} concentration varies from the natural content of (75%) to 64 or 80% depending on the isotopic molecule selected for irradiation.

It must be noted that the high potential possibilities of electron photochemistry for laser separation of isotopes still have not been demonstrated to a sufficiently high degree, as could be expected for this old classical approach. This can be explained by several causes. First of all, as was noted in the introduction, the problem of loss of selectivity in the secondary processes is much more serious for photochemical methods than for photo-physical methods. For example, even in such an ideal case as the reaction of selectively excited metastable mercury atoms, the enrichment coefficient as a result of secondary processes does not exceed 14, in spite of the set of experiments performed [86]. Secondly, the method of electron photochemistry, judging by the published papers [4-7], is not prospective for separation of uranium isotopes, on which probably the majority of researchers have worked. Thirdly, the energetics of the visible and ultraviolet lasers are still very far from the economically advantageous indexes and powerful lasers in this range still are difficult to obtain.

b) Oscillatory Photochemistry

The rate of the chemical reaction can be significantly increased on oscillatory excitation of the reacting molecules. Gibert [95] proposed this method for laser separation of isotopes in 1963. However, the first successful experiment by this method was performed more than 10 years later [96].

For the excitation of oscillatory levels it is possible to use a large number of different systems (Fig 12). The basic oscillation which is active in absorption can be excited on absorption of a total of one photon (Fig 12,a). The excitation of the component or overtone band generates two or more quanta of oscillatory excitation in the molecule on absorption of one photon with higher energy (Fig 12, b). The high oscillatory levels can also be achieved by stepped excitation through one or more intermediate oscillatory levels by multifrequency laser radiation (Fig 12, c). For excitation it is also possible to use the process of the combination type (Fig 12, d). This is the only method of excitation of oscillations with zero dipole moment of the transition (for example, the homonuclear diatomic molecules). The selective excitation of the higher oscillatory levels for multiphoton absorption of infrared radiation with comparatively moderate powers (10^6 to 10^7 watts/cm²) gives another one and, probably, the only effective method of direct excitation of the oscillatory levels with an energy of several electron volts (Fig 12, e). All of these excitation schemes were tested in experiments with respect to laser separation of the isotopes [4, 5]. Positive results were obtained using the last three excitation schemes (Fig 12, c-e). However, the number of experiments performed is still small,

and therefore it is now impossible to talk about the organic defects of any of them. The success or failure of one experiment or another is more connected with the selection of experimental conditions and the appropriate acceptor than with the excitation scheme, although, of course, the schemes with excitation of high oscillatory levels are preferable, inasmuch as they potentially insure a broader selection of possible chemical reactions and lower effect of the thermal mechanism of decreasing the selectivity of the separation.

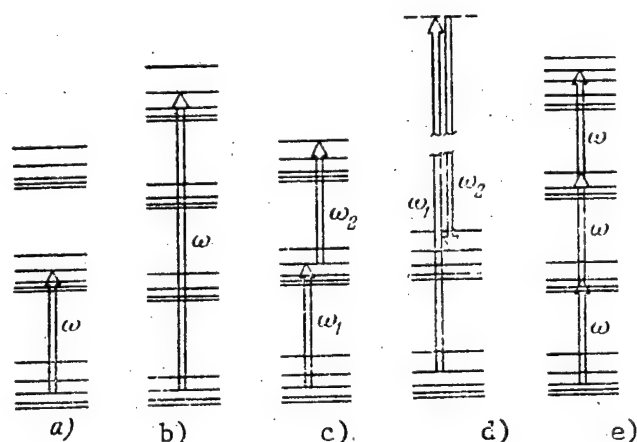


Figure 12. Schematics of the selective excitation of oscillatory levels of molecules by laser radiation

a) Absorption of one photon on the basic band; b) absorption of one photon on the second overtone band; c) two-stage excitation in the two-frequency infrared field; d) Raman excitation of the oscillation inactive in the infrared absorption with two-frequency laser emission the visible range; e) multiphoton excitation of high oscillatory levels by single-frequency intense infrared radiation.

Arnold, et al. [96] reported on the enrichment by Cl^{35} isotope as a result of increasing the reaction rate of the Br atoms with the HCl molecules. They used the pulse chemical HCl-laser for successive excitation of the HCl molecule from the state of $v=0$ to the state $v=1$ and then to the state $v=2$ (Fig 12, c). The selective excitation of HCl led to acceleration of the reaction $\text{Br} + \text{HCl}^{35} (v=2) \rightarrow \text{HBr} + \text{Cl}^{35}$ by approximately 11 orders of magnitude by comparison with the reaction rate of the Br atoms with HCl ($v=0$). The isotopic enrichment was measured by mass spectral analysis with time resolution of the BrCl molecules formed in the secondary process of $\text{Cl} + \text{Br}_2 \rightarrow \text{BrCl} + \text{Br}$. For equal Br and HCl pressures, the separation factor reached two.

Recently Panfilov, et al., succeeded in observing the enrichment of carbon isotopes in the reaction of selectively excited $\text{C}^{(i)}\text{H}_3\text{F}$ molecules with bromine atoms [97]. Although the enrichment factor was small, this experiment is of interest from the point of view of using a continuous IR laser.

The Raman excitation of the N_2 molecules in the air at 77°K was used by Basov, et al. [98, 99] to obtain NO molecules enriched with the N^{15} isotope by 100 times. This can occur as a result of the reaction of $N_2^* + O_2 \rightarrow 2NO$.

Basov, et al. interpreted their results in terms of the mechanism of [100, 101] based on the oscillatory exchange of excitation between the N_2 molecules under the operating conditions of the high level pumping mechanism investigated by Treanor, et al. [102] (see the survey [103]). The same method of separation and the same interpretation were used by Basov, et al., in the experiments with respect to the separation of isotopes in an electric discharge, where the enrichment of the NO with the N^{15} isotope reached 10. However, the results of this work are in contradiction with reference [104]. Therefore the interpretation of the results in references [98, 99] cannot be considered final.

On pumping of the BCl_3 molecules in a mixture of $BCl_3 + H_2S$ and $BCl_3 + D_2S$ by focused pulses of the CO_2 -laser which probably excited quite high oscillatory levels of the BCl_3 , separation of the boron isotopes [105] was obtained. Irradiating the mixture with a natural content of boron isotopes either by the P(16) line or the R(20) line of the 10 micron band of the CO_2 -laser, it was possible to obtain enrichment of the residual BCl_3 K (10/11) of about 1.7 and K (10/11) \approx 0.7 respectively. Now it is clear that this experiment is intermediate between the single quantum infrared photochemistry in a weak field and the multiphoton infrared photochemistry in a strong field.

An attractive characteristic of oscillatory photochemistry for the separation of the isotopes is the possibility of using infrared photons with slow energy of the highly efficient molecular laser for obtaining high output capacity of the process. However, from the point of view of effective utilization of infrared photons, the methods of multiphoton excitation and dissociation of multiatomic molecules in an intense infrared field will compete strongly with the method of infrared photochemistry of molecules. The multiphoton approach has a number of deficiencies by comparison with oscillatory photochemistry (in particular, the applicability only to multiatomic molecules), but, in turn, it is much less critical with respect to any other conditions. The following experiments undoubtedly will indicate the regions of predominate use of each approach.

7. Obtaining Pure Materials

The methods of selective photophysics and photochemistry developed for the separation of isotopes offer the possibility of developing a new approach to the technological nature of matter on the atomic-molecular level when by using laser emission it is possible directly to manipulate the atoms and molecules of defined variety, that is, to collect microscopic amounts of matter "with respect to one atom, with respect to one molecule." The most important process of laser atomic-molecular universal technology of matter is undoubtedly obtaining especially pure materials in the atomic state, alloys and molecular compounds. In order to obtain especially pure materials or to purify the material to remove impurities it is possible to use the

processes of selective photoionization of atoms and selective photodissociation of molecules. The possibilities and the areas of application of them of course differ significantly.

Selective Photoionization of Atoms

This approach to the technology of matter is the most universal and flexible. The optimally selected scheme for selective photoionization of the atom under the effect of two (or theoretically a larger number) laser beams with tunable frequencies in a defined way and selected intensities permits ionization of each atom during the time 10^{-5} to 10^{-7} seconds. With 20% utilization of the radiation energy with an average power of 10^3 watts for photoionization of atoms with an energy of $E_i \sim 7$ to 8 eV, it is possible selectively to ionize about 1 mole of matter per hour. Consequently, a device of comparatively small scale can theoretically provide for obtaining several tons of pure material a year. Therefore the method of selective ionization of atoms combined with tunable lasers with an average output of 100 to 1000 watts can be considered as a quite efficient method of fine separation of matter on the atomic level [106].

The laser purification of matter by the method of selective ionization [106] must have a number of significant advantages by comparison with the existing methods of purification of matter based on the difference of certain chemical or physical properties of the purified matter and impurities:

1) High selectivity or high degree of purification in a single process. The degree of purification in the process of the separation of the given elements from any impurities can reach values of more than 10^3 . This value is determined by the process of charge exchange and collision of an ion of given element with a neutral atom of the impurities. Theoretically by lowering the density of the atoms in the beam it is possible to achieve selectivity of the separation much higher than 10^3 with corresponding reduction of the output capacity. In particular, if we take the material from mass production for purification with a purity of $10^{-7}\%$, then by the method of selective ionization of the atoms it is possible to realize purification to $10^{-10}\%$.

2) Universality. The selective ionization can be realized by corresponding selection of the frequencies of the laser beams in practice with any element independently of its physical and chemical properties (melting point, boiling point, reactivity, and so on). If it is necessary to purify the material with respect to one or several defined elements, then selective ionization of only the impurities and removal of them from the atomic beam of the matter is possible. The maximum productivity of the method and minimum expenditures of coherent light energy are achieved in this regime.

3) Flexibility permitting direct use of ion beams to obtain pure films or introduce ions into a uniform material (ion alloying). An ion beam can be directed toward the surface of the substrate in order to obtain the pure film of the given element. It appears possible to have simultaneous

independent selective ionization of two or three elements in different beams and deposition of their ions on the same surface. Thus, obviously it will be possible to obtain films of complex atomic compounds, the stoichiometric composition of which is controlled by the intensity of the photoion beam. The entire process of selective ionization of the atoms, extraction of the ions from the beam and deposition of them on the substrate can be realized in a deep vacuum. The process does not require the contact of the purified material with any reagents or materials except the substrate, for which it is always possible to use a material without undesirable impurities.

It is worthwhile to pay separate attention to the application of selectively formed photoions of boron, arsenic, phosphorus, and other elements in the devices of ion alloying of semiconductors [35]. The electrodeless laser for generation of ions of a given variety first of all eliminates the necessity for using an electromagnetic mass separator and, secondly, it permits structural separation of the high temperature source of atoms and the ionizer. The latter is important, for it permits photoionization of the atoms to be realized near the high voltage electrode and, consequently, can significantly simplify the structural design of the electrostatic ion accelerators on an energy on the order of Mev, and higher.

The basis for the successful development of the photoionization method is, first of all, the development of optimum schemes for multistage selective ionization of various elements and, secondly, the development of sufficiently effective UV and visible band lasers with tunable frequency, a high average power and large reserve. The universal and optimal ionization scheme insuring high excitation cross section and high ionization yield is the multistage resonance excitation of the states near the ionization boundary and subsequent autoionization of highly excited atoms by a pulse electric field proposed in reference [33]. The first experiment demonstrated the reliability of this approach [39, 40]. As for lasers, the existing basic difficulty with the UV band lasers obviously will be overcome by using excimer lasers.

b) Selective Dissociation of Molecules

This process can be used for the purification of matter in the gas phase to remove molecular impurities, the removal of which by ordinary methods has low effectiveness. The possibility of purification by the method of dissociation of impurity molecules is based on the difference of the physical-chemical properties formed as a result of the dissociation of the products and the basic material. At the end of the process after irradiation of the mixture this makes it possible to use standard purification methods.

Recently the possibility of the purification of matter in the gas phase by dissociation of the impurity molecules by powerful infrared radiation was demonstrated experimentally [107] in the example of the purification of arsenic trichloride AsCl_3 to remove the impurities of 1,2-dichloroethane $\text{C}_2\text{H}_4\text{Cl}_2$ and carbon tetrachloride CCl_4 . The ordinary methods of purification give a minimum content of these impurities on the order of 10^{-2} to $10^{-3}\%$.

The absorption bands of the impurity molecules of $C_2H_4Cl_2$ and CCl_4 enter into the region of generation of the CO_2 -laser where there is no complete absorption of the molecules of the basic material $AsCl_3$ (Fig 13). Therefore for selective dissociation it was possible to use the effect of dissociation of the multiatomic molecules in a strong field of a CO_2 laser. The final products of dissociation were identified by the infrared absorption spectra (for $C_2H_4Cl_2$) and the mass spectra (for CCl_4). In the experiments [107] the selective dissociation of the impurities $C_2H_4Cl_2$ and CCl_4 in $AsCl_3$ was clearly observed for a pressure of the latter on the order of 10 torr. The initial content of the impurity molecules was comparatively large, which is connected not with the restrictions of the method but only with the sensitivity of the recording. In the case of 1,2-dichlorethane, the products formed differ sharply with respect to their physical properties from the $AsCl_3$ which permits easy separation of them and insurance of purification of the $AsCl_3$. Recently in Los Alamos [108], the possibility of selective dissociation of the impurity molecules (PH_3 , AsH_3 , B_2H_6) by ultraviolet radiation of ArF of an excimer laser on irradiation of SiH_4 molecules was demonstrated. The selectivity was based on the stronger absorption of ultraviolet radiation with a wave length of 193 nm by the impurity molecules. The laser purification of monosilane is of practical interest for the process of obtaining pure silicon in the semiconductor industry [108].

The method of selective dissociation of molecules is applicable obviously not only in the technology of pure materials but also for purification of gas mixtures to remove toxic and carcinogenic materials, that is, in the selective atmospheric photochemistry. If the dissociation of these impurities converts them to inactive forms, the method will become quite simple and independent.

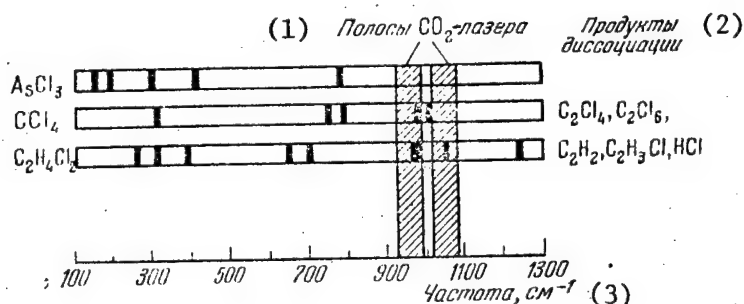


Figure 13. Purification of $AsCl_3$ gas by the method of selective dissociation of the impurity molecules CCl_4 and $C_2H_4Cl_2$ by CO_2 -laser emission

Key:

1. CO_2 -laser band
2. Dissociation products
3. Frequency, cm^{-1}

8. Selective Laser Biochemistry

The selective effect of laser radiation on the complex molecules of a condensed medium is a serious possibility with respect to its consequences for molecular biology, but it has been little studied and is inobvious. In the case of a condensed medium at normal temperatures, the contradiction between the requirements on the possibility of selective excitation and the possibility of maintaining selectivity of excitation has been sharpened greatly. The electron states of the biomolecules have been grouped in the ultraviolet range and it is quite difficult to calculate them for high selectivity of excitation of the selective molecules in a mixture. On the other hand, the electron excitation is retained, as a rule, for a time (approximately 10^{-9} seconds) sufficient for the photochemical reaction with noticeable quantum yield [109]. The oscillatory excitation of the molecules is much more selective, but it relaxes to heat in a short time (at 300°K the relaxation time $T_1^{\text{col}} \leq 10^{11}$ sec). Inasmuch as the energy of one oscillatory function differs a total of several times from the thermal energy kT , it is difficult to expect noticeable contribution to the biochemical reaction rate of the short-lived oscillatory selective excitation by comparison with the constantly effective thermal nonselective excitation.

The successful experience in the realization of isotopically selective photoprocesses in a gaseous environment indicates at least two possible paths of eliminating this contradiction: 1) the combination of selective oscillatory excitation with subsequent electron excitation from the oscillatory-excited states, that is, the two-stage IR+UV excitation, 2) multiphoton oscillatory excitation in a strong IR field. Of course, in both cases the process, in contrast to the case of a gaseous medium, must be realized under the effect of picosecond pulses in order that the molecule be able to absorb the noticeable energy of several electron volts to thermal relaxation of the oscillatory excitation. The process of the two-stage IR+UV excitation in which only the additional advantages of the oscillatory and electronic excitation are definitely summed appears to be especially universal. Of course, in each specific case it is necessary to prove first the potential realizability of the two-stage IR+UV-selective photoprocess for the selected molecule in solution or the molecular bond in the macromolecule. The meagerness of the spectral data, especially on the excited states for the biomolecules makes the answer to this question far from trivial. Below, we shall consider several potential possibilities for the different molecules and bonds. However, in addition to this general problem there are also other "cavern" problems, in particular: 1) the heating of a medium in the process of selective photoexcitation; 2) absorption of the infrared radiation by the molecules of the solvent. These problems are especially significant for the experiments *in vivo*.

The estimates made in reference [110] indicate the possibility of eliminating heating for molar concentrations of the molecules in solution of less than 10^{-3} M and sufficiently weak absorption of the infrared radiation by the solvent molecules. For attenuation of the infrared absorption by the

molecules of the standard solvent -- water -- in the experiments in vivo it is possible to try to excite the overtones and the component oscillations in the near IR region, in spite of the decrease in the selective absorption cross section. In certain cases the absorption probably can be significantly reduced, working in the "induced self transparency" mode for the solvent molecules. The selective excitation of the oscillatory levels with the help of a stimulated Raman process in the field of the two-frequency visible laser emission which is entirely transparent for the solvent as was done in experiments [111] is also possible. The estimates indicate that the required intensities of the IR and UV pulses with a duration of 10^{-11} to 10^{-12} sec are in the 10^8 to 10^9 watts/cm² range. Of course, the cooling of the molecules lowers the rate of V-T-relaxation, and therefore sharply attenuates all of the difficulties.

Let us now consider several specific possibilities in laser selective biochemistry [112]. They are quite obvious "on paper," but can turn out to be the most difficult experimentally.

a) Selective Excitation of Bases in DNA

The polynucleotide chain molecules of DNA and RNA appear to be an important subject both from the point of view of the possibility of selective laser mutations and from the point of view of simplicity of their structure. In spite of their colossal size, both molecules contain five recurrent nucleotides: guanine (G), cytosine (C), thymine (T), adenine (A) and uracyl (U). All five of these bases are purine and pyrimidine rings having similar UV spectrum with two peaks in the 4 to 6 ev range. Obviously it is possible to count on selective electron excitation of the long-wave band of the G and C bases corresponding to the excitation of the π -electron system of the pair of bases G-C [113]. At the same time it is impossible to excite the A and T nucleotides without touching on the excitation of the remaining nucleotides.

The difference of the molecular structure of the indicated nucleotides permits hope of detection of a specific oscillatory band for each of them which is exhibited in the UV absorption spectrum. In Fig 14 as an example the UV and IR spectra of thymine are presented. Here the possible shift of the UV absorption boundary as a result of excitation of the IR band in the range of 1600 cm^{-1} caused by the vibrations of the double bonds C=C and C=O in the ring is demonstrated. Let us note that the IR spectra of DNA have been insufficiently investigated [115] to be able to indicate the specific frequencies for all of the nucleotides at the present time. It appears that the excitation of the vibrations of the DNA nucleotides by picosecond IR pulses that are tunable with respect to frequency and simultaneous sounding of the variation of the UV spectrum is a good method for investigation and deciphering the vibrational spectrum of the DNA and the required intermediate step in the investigation of the possibility of selective effect on the base of the DNA.

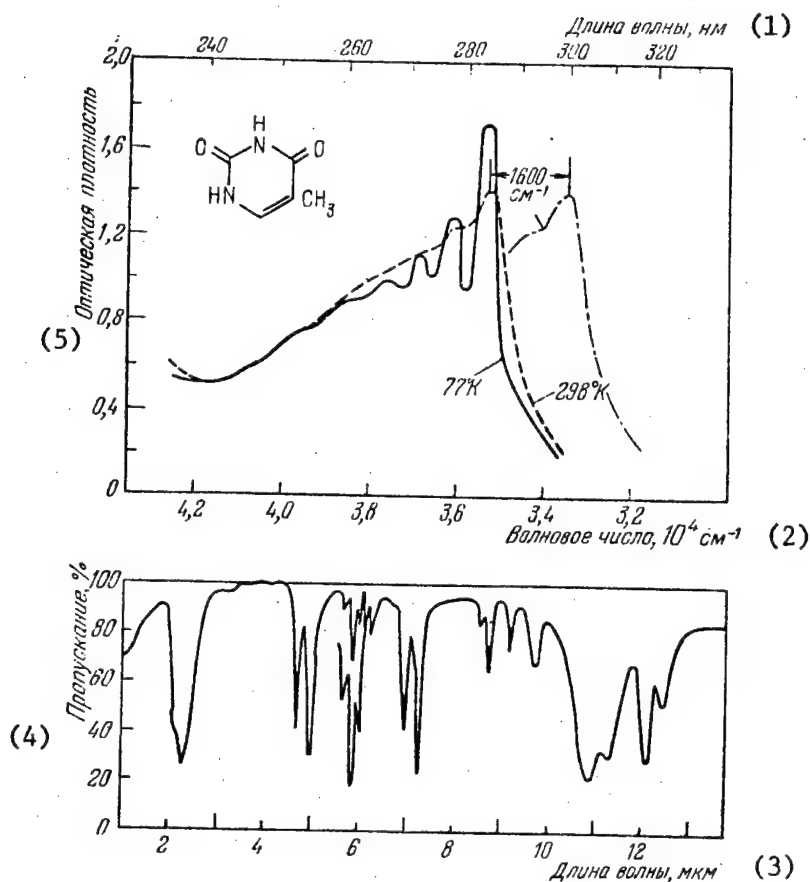


Figure 14. UV and IR absorption spectra of thymine (according to the data of references [109, 114])

Key:

- | | |
|--|--------------------|
| 1. Wave length, nm | 4. Transmission, % |
| 2. Wave number, 10^4 cm^{-1} | 5. Optical density |
| 3. Wave length, microns | |

The first experiments with respect to the two-step IR+UV-excitation of the electron state of the complex molecule in solution under the effect of picosecond pulses of IR and UV radiation were performed recently in reference [116] (cumarine molecules in CCl_4) and in reference [117] (molecules of rhodamine B in D_2O). The experiment [117] demonstrates the basic difficulties of the experiments with biomolecules and the means of overcoming them. As is known, the biomolecules usually are found in an aqueous solution. The strong absorption of water in the infrared region can be overcome by the use of overtones for the excitation and also by the application of heavy water as the solvent which has the infrared absorption spectrum shifted to the long-wave region. For investigation of the two-step excitation complex molecules, the two-channel parametric generator of single ultrashort (lasting 10 picoseconds) pulses with smooth tuning of the frequency in the band of 0.26 to 4.0 microns was used. The infrared channel is designed for excitation of the oscillatory transitions (the

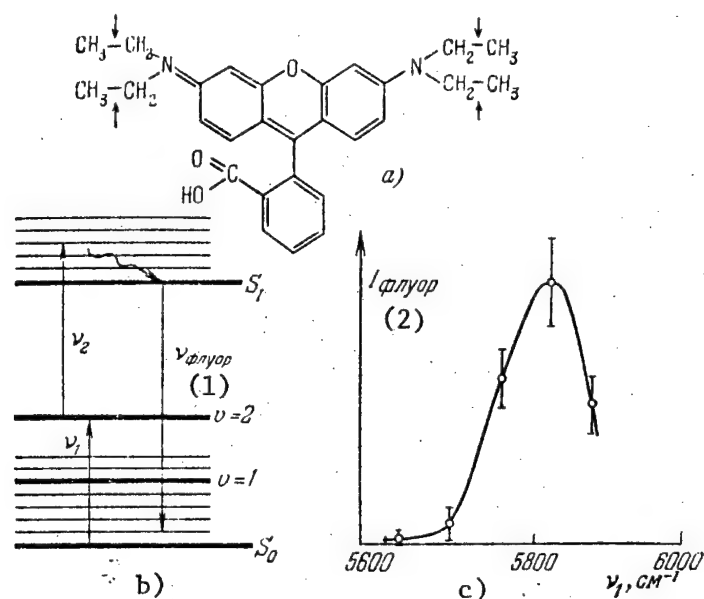


Figure 15. Selective two-stage excitation of the electron state of the rhodamine B molecule in a solution of D_2O by the joint effect of two ultrashort pulses with frequencies of ν_1 and ν_2

a) Structure of the rhodamine B molecule. The arrows indicate the excited vibrations of the molecular group; b) schematic of the two-stage excitation and observed fluorescence; c) dependence of the fluorescence intensity on the frequency ν_1 of the tunable infrared radiation [117]

Key:

1. $\nu_{\text{fluorescence}}$
2. $I_{\text{fluorescence}}$

tuning range of 1.5 to 4.0 microns), and the short-wave channel, for excitation of the electron states (the tuning range of 0.26 to 1.6 microns). The first overtones of the asymmetric stretching vibrations of the methylene and methyl groups of rhodamine B in the 5800 cm^{-1} range were used as the intermediate vibrational states. These overtones are very weak and usually not exhibited in the infrared spectrum. The excitation of the electron state was recorded with respect to the occurrence of fluorescence under the joint effect of two ultrashort pulses. The selectivity of the excitation was controlled by measuring the intensity of the fluorescence on tuning the frequency of the infrared radiation (Fig 15). The experimental resonance function gives clear information about the spectrum of the weak overtone of vibration of the methyl group CH_3 not observed by ordinary methods of spectroscopy.

b) Selective Excitation and Breaking of the Hydrogen Bonds in DNA

The double spiral of the DNA is formed by hydrogen bonds between the bases (guanine-cytosine and adenine-thymine). The breaking of the hydrogen bonds

must lead to splitting of the double spiral into two single chains and to subsequent replication of the DNA. Obviously, the selective excitation of the hydrogen bonds and the selective breaking of them is of interest for laser control of the DNA replication process [112]. It appears to me that it is important not only as a potential possibility of the laser stimulation of the biological process rate but also as a theoretically new possibility of external controllable "starting" of the DNA replication process, the details of which have still not been fully explained.

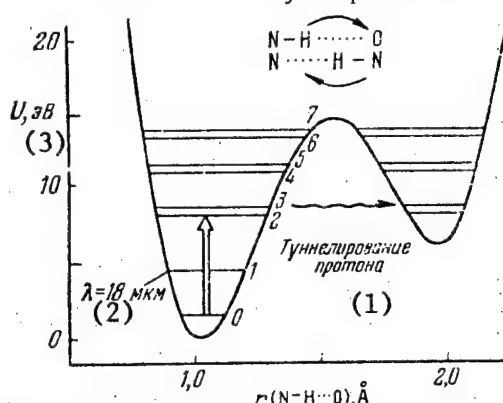


Figure 16. Potential function of the hydrogen bond in DNA (from reference [113]) and the possible schematic of the excitation of the levels of the infrared laser radiation for stimulation of proton tunneling

Key:

1. Proton tunneling
2. $\lambda = 18$ microns
3. U , eV

The two pairs of bases in the DNA have somewhat different hydrogen bonds. The A-T pair of bases is connected by two hydrogen bonds $N-H \dots O$, and to break this pair of bases an energy of about 7.0 kcal/mole is required. The G-C pair of bases is connected by two hydrogen bonds $N-H \dots O$ and one bond $N-H \dots N$, and to split them it is necessary to expend an energy of about 9.0 kcal/mole [113].

The G-C bond in the native DNA corresponds to the infrared absorption band of about 1720 cm^{-1} , and the A-T bond, the band at about 1700 cm^{-1} . On denaturation of the DNA when the hydrogen bonds are broken, both of the indicated bands disappear [115]. Therefore, in reference [110], it was proposed that the picosecond powerful pulses of infrared radiation be used on these frequencies (5.814 and 5.888 microns) for stimulation of the breaking of the hydrogen bonds. Of course, there are much greater possibilities here, especially from the point of view of the selection of the more suitable wave lengths not absorbed by the solutions or the experiments in vivo.

The potential function of the hydrogen bond has two characteristic minima corresponding to two possible spatial and energy positions of the proton (Fig 16). The energy levels of the proton of the hydrogen bonds $N-H \dots O$ and $N-H \dots N$ [113] were calculated although they have still not been

detected experimentally. It is considered that the transition of the protons (more precisely, two protons in the pair of close hydrogen bonds) in the energywise higher tautomeric state leads to mutation (the Lowdin mechanism [118]). It is clear that by using a laser with a wave length of 1.8 microns it is possible to try to convert the proton to the excited state and at the same time stimulate tunneling of it to a higher energy minimum. This possibility was discussed in reference [113] and with the development of the engineering of picosecond tunable lasers in the infrared band it must become the object of experimental research. The excitation of the proton must also be exhibited in the electron ultraviolet absorption spectrum and, consequently, can be used for realization of the two-step selective process by the following scheme: "selective infrared excitation of the proton vibrations with ultraviolet excitation of the electron."

9. Selective Detection of Nuclei, Atoms and Molecules

The methods of selective laser photophysics theoretically solve the problem of physical extraction of an atom or a molecule of strictly defined variety from a mixture of other atoms and molecules highly similar with respect to chemical properties. Of course, the first and relatively simpler part of this problem is the selective detection of the single atoms and molecules. In particular, for this purpose the method of selective two-stage (or multi-stage) photoionization of the atoms and molecules is the most convenient. This possibility has been discussed more than once by the author in a number of lectures and surveys of laser spectroscopy [112, 119-122]. The proposal of the method of selective photoionization for detection of atoms and molecules is contained in the previous paper [19]. Let us consider some of the potential possibilities available here.

a) Detection of Excited Nuclei

Now the excited (metastable) nuclei are detected only by the processes of the radioactive decay. However, the individuality of the excited nucleus is reflected not only in the nuclear transitions but also in the superfine structure of the optical transitions of the electron shell surrounding the nucleus. Since the isomeric structure usually noticeably exceeds the upper broadening of the spectral lines, it appears entirely possible to have selective photoionization not only of the nuclei of defined isotopic composition but also the excited nuclei with defined nuclear spin and quadrupole moment. This possibility has already been discussed from the point of view of the spreading of the isomeric nuclei in the preparation of the active medium of the future γ -laser [123]. Here we shall emphasize the possibility of selective detection of the excited nuclei as a new approach in the investigation and search for the metastable nuclear levels. With respect to the electron "coat" of the nucleus it is possible, without deexciting the nucleus during the process of detecting it, to determine the quantum state of the nucleus. After each selective separation of an electron and detection of it it is possible to recharge the ion and in this way repeat the entire process a multiple number of times.

b) Detection of Single Atoms

The selectively excited atom can be ionized with quantum yield close to one if the energy density of the ionizing laser pulse exceeds the saturation energy density $\mathcal{E}_{\text{fac}}^{(i)}$ [Key: (i) sat] of the induced transition of the excited atom to the continuum, that is,

$$\mathcal{E}_{\text{ion}}^{(1)} \geq \frac{\hbar\omega_2}{\sigma_{ie}} = \mathcal{E}_{\text{fac}}^{(i)} \quad (2)$$

Key:

1. ion
2. sat

where σ_{ie} is the photoionization cross section from the excited state "e," and the duration of the ionizing laser pulse is less than the relaxation time of the excited state. For the standard value of the photoionization cross section $\sigma_{ie} = 10^{-17}$ to 10^{-18} cm² for $\hbar\omega_2 = 2$ eV the energy density of the photoionizing laser pulse must lie in the range of \mathcal{E}_{ion} [ion] = 0.03 to 0.3 joules/cm². The experimental study of the dependence of the ionization yield on the energy of the ionizing pulse was performed in reference [124] for the Rb atoms. Fig 17 shows the experimental dependence of the total ion yield on the energy density \mathcal{E}_{ion} . The intersection point of the linear part of the curve with the curve reaching the plateau (point A) corresponds to the energy density $\mathcal{E}_{\text{fac}}^{(i)}$ [(i) sat] for which 63% of the excited ions are ionized.

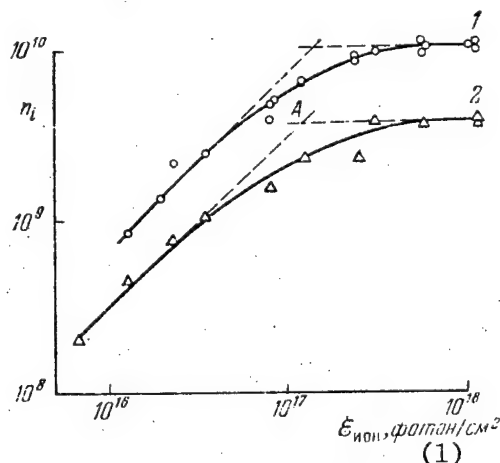


Figure 17. Total photoion signal as a function of the energy density \mathcal{E}_{ion} [ion] of the laser pulse ionizing the Rb atoms excited to the 6 ²P-state for two different values of the intensity of the electric field (1-2,4 kv/cm; 2-1 kc/cm), drawing out the photoions [124].

Key:

1. ion, photon/cm²

The first successful experiments with respect to the detection of single atoms (in the example of Cs) by the method of two-stage photoionization were realized in reference [125], where the ionized atom in the chamber of the proportional counter caused a signal which is entirely sufficient for detection of the single act of selective photoionization. When satisfying the conditions of saturation of the exciting and ionizing induced transitions where the quantum ionization yield is close to one, it is possible in this way selectively to detect the single atoms. From the point of view of detection of single atoms with known expenditures of laser energy, the most advantageous is the selective photoionization scheme to the highly excited, so-called Rydberg states. This method of detecting the single atoms was first realized in reference [126]. Its universality and flexibility permit broad use of it both in scientific and applied analytical problems. In particular, this method is entirely applicable for finding new heavy and superheavy elements [127] and also atoms with superdense nuclei [128]. The optical spectrum of the atom -- the superfine structure of the line -- is its "certificate," guaranteeing uniqueness of the detection and identification of the new element or new nucleus. Therefore the element of selective photoionization is of great interest for such experiments [121].

b) Detection of Complex Molecules

As is known, the selective detection of trace amounts of multiatomic complex molecules is an exceptionally complex problem still unsolved with the help of physical methods. Now the standard method of detection and identification of the complex molecules is the mass spectral analysis, but its sensitivity is insufficiently high, and the selectivity of detection of the complex molecules distinguished only by the spatial structure is in practice absent. Therefore the development of new methods of solving this problem is extremely important and urgent.

The method of selective photoionization of the molecules by laser radiation can be used as the basis of the so-called laser mass spectrometer [18], the general diagram of which was presented in reference [121]. The laser with tunable frequency ω_1 realizes selective excitation of the oscillatory (for certain molecules electronic) state of the molecules (Fig 18). As a result of this excitation, the edge of the photoionization band of the molecule usually lying in the VUV-band is shifted by a small amount. The second laser which emits in the VUV-band realizes photoionization of the molecule. Its frequency ω_2 is selected in the region of maximum inclination of the edge of the photoionization band. In this case the preliminary selective excitation of the molecules by the tunable laser for a comparatively small value $E_{exc} \sim 0.1$ to 0.5 eV causes detectable change (10^{-1} to $10^{-2}\%$ considering the molecule distribution with respect to rotational states) of the photoionization cross section, that is, a change in the magnitude of the photocurrent. The photoions are directed to the ordinary mass spectrometer which realizes measurements of the mass spectrum, that is, measurement of $i=f(M/e)$. In addition, in the given version of the mass spectrometer it is possible to measure the magnitude of the photocurrent for the given value

of M/e as a function of the frequency of the tunable laser ω_1 . In this case, the IR spectrum of the trace amounts of the complex molecules will be measured inasmuch as on comparison of the frequency of the tunable laser ω_1 with the absorption frequency of the molecules, transition of the molecule to the excited state will occur and, consequently, a change in amplitude of the ion photocurrent. The laser mass spectrometer with selective photoionization of the molecules instead of the ordinary non-selective ionization by the electron beam (or continuous VUV radiation) will give simultaneously optical (IR and visible) absorption spectrum and mass spectrum. Thus, it is possible to obtain information about the spatial structure of the molecules with identical mass, and so on.

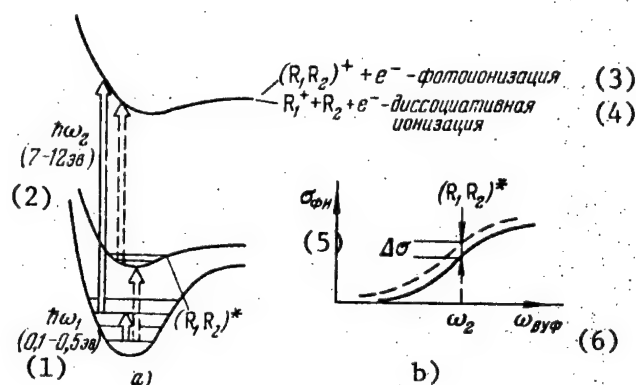


Figure 18. Explanation of the selective two-stage photoionization of molecules by laser emission

a) Schematic of the transition; b) variation of the photoionization cross section for selectively excited molecules

Key:

1. 0.1 to 0.5 eV
2. 7-12 eV
3. Photoionization
4. Dissociative ionization
5. σ_{PI}
6. ω_{VUV}

We began a systematic study of this method of detecting molecules after the development of a simple VUV H_2 -laser [129]. As the first step, single-step photoionization was carried out on the molecules of dimethylaniline and methylaniline by the irradiation of an H_2 -laser in the 1600 Angstrom range [130] and also the molecules by the NO-laser radiation in the 1200 Angstrom range. Then [30] we realized the two-step photoionization of the H_2CO molecules by the joint effect of the radiation pulse of the N_2 laser with a wave length of $\lambda_1=3371$ Angstroms, exciting the states 1A_2 and the emission of H_2 -laser with $\lambda_2=1600$ Angstroms realizing photoionization of the excited molecules (Fig 19, a). The ionization potential

of the H_2CO molecule is $E_i=10.87$ eV, and the total energy of the two-laser quanta $h\nu_1+h\nu_2=3.7+7.7$ eV = 11.4 eV, which is entirely sufficient for the photoionization of this molecule. The time delay of the pulse of the H_2 -laser (the duration is shorter than 1 nanosecond) was varied with respect to the pulse of the N_2 -laser (duration of about 2 nanoseconds), which permitted measurement of the dependence of the photoion yield on the delay time (Fig 19, b). The experimental curve was close to the exponential function with damping constant of 15 ± 2 nanoseconds which is equal to the lifetime of the H_2CO molecule in the excited $^1\text{A}_2$ -state. With inverse order to repetition of the pulses of the N_2 and H_2 lasers the H_2CO photoionization signal is absent.

In the experiments [131] a study was made of the two-step photoionization of the NO_2 molecule on excitation of the intermediate electron state by the emission of a tunable dye laser (the transition $^2\text{A}_2 \rightarrow ^2\text{B}_1$ in the 4470 to 4970 Angstrom range). The photoionization of the excited molecules was realized by the VUV pulse of H_2 -laser in the 1660 Angstrom range. The ionization potential of the NO_2 is equal to 9.78 eV, the energy of the two laser photons is equal to $2.7+7.7$ eV=10.4 eV, so that the molecule NO_2 can be photoionized only as a result of the two-stage process. By measuring the dependence of the photoion current on the dye laser frequency, the absorption spectrum of the NO_2 molecule was measured at the electron transition.

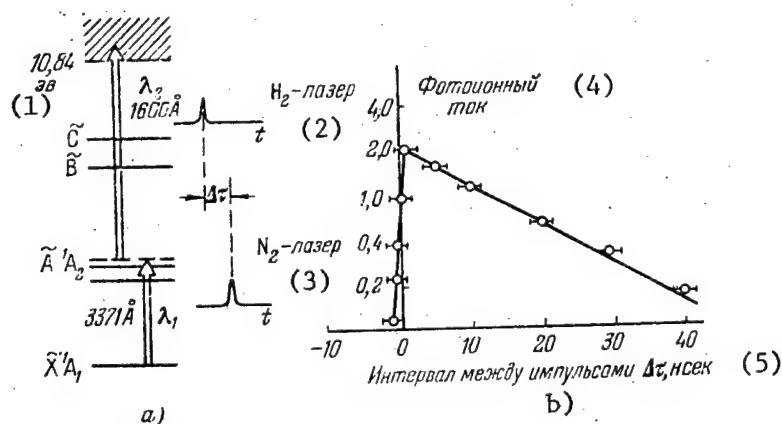


Figure 19. Two-step photoionization of the H_2CO molecule by the joint effect of the pulses of N_2 and H_2 -lasers
a) Schematic of the transitions; b) photoion yield as a function of the time interval between pulses [30]

Key:

1. 10.84 eV
2. H_2 -laser
3. N_2 -laser

4. Photoion current
5. Interval between pulses, $\Delta\tau$, nanoseconds

Finally, successful experiments were recently performed with respect to photoionization of molecules by laser emission in a molecular beam of a mass spectrometer [132]. The schematic of the laser photoionization mass spectrometer created jointly by the NIFKhI Institute imeni L. Ya. Karpov and the Institute of Spectroscopy of the USSR Academy of Sciences is presented in Fig 20. First a single step photoionization of the dimethylaniline molecules was realized, and so on, in a beam by radiation of the H_2 -laser which increased its photoion current by several orders. Then the two-stage photoionization of the diacetyl molecule was realized by the joint effect of the UV pulses of the N_2 lasers and the VUV pulses of the H_2 lasers [133]. The simultaneous observation of the dependence of the ion yield on their mass (measurement of the mass spectrum), the wave length of the exciting radiation (measurement of the optical spectrum), the time interval between the two laser pulses (measurement of the damping time of the intermediate state) give a large volume of information entirely sufficient for detection and identification of the exceptionally small concentrations of complex molecules. Of course, for solving the problem of identification of the complex molecules, the two-step (or multistep) photoionization of the molecules with excitation of the intermediate oscillatory states by radiation of a tunable infrared laser must be investigated and realized in practice.

The infrared mass spectrometer promises to be a universal, highly selective and highly sensitive detector of the complex molecules for the solution of many scientific and applied problems. Actually, inasmuch as the detection of the excited molecules by the method of photoionization is very highly sensitive, it is possible to count on measurement of the infrared spectrum of extraordinarily small amounts of material which must be somewhat less than in the best existing classical and laser infrared spectrometers. It is necessary to add to this the possibility of realization of the simultaneously extraordinary high spectral resolution which theoretically is determined only by the residual doppler broadening as a result of the angular aperture of the molecular beam. Here we obviously approach the solution of the theoretical problem of the creation of physical methods for the detection and identification of small amounts of impurities of organic material for the first time with the improvement which is achieved by the olfactory organs of man and animals [121].

10. Spatial Localization of Molecular Bonds

The selective effect on the molecular bonds of laser radiation opens up the theoretical possibility of the spatial localization of the given molecular bonds, that is, mapping the macromolecules. The idea of this approach can be under study in the example of the so-called photoelectron (photoion) laser microscope [17], the schematic of which appears in Fig 21. In contrast to the ordinary autoelectron or autoion Muller projector (see [134]), the electron or ion is separated from the molecule selectively under the effect of the laser irradiation, and not as a result of the nonselective autoionization in a powerful electric field. After the electric field only the electron or ion transport function is left with respect to the radial

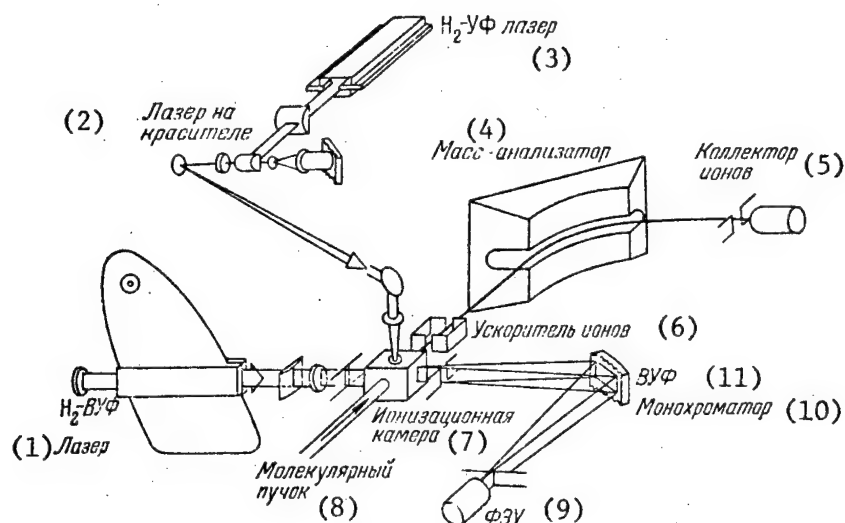


Figure 20. Schematic of a mass spectrometer with selective two-step photoionization of the molecules in the beam by the joint effect of the pulse of the tunable dye laser and the pulse of the vacuum ultraviolet H₂-laser [133]

Key:

- | | |
|------------------------------|------------------------------|
| 1. H ₂ -VUV laser | 6. Ion accelerator |
| 2. Dye laser | 7. Ionization chamber |
| 3. H ₂ -UV laser | 8. Molecular beam |
| 4. Mass analyzer | 9. FEU (Photomultiplier) |
| 5. Ion collector | 10. Monochromator |
| | 11. VUV [Vacuum Ultraviolet] |

trajectories to the screen of the projector. The selective photoionization of the defined molecular bonds in the macromolecule located on the tip of the projector can be realized by the multistep scheme under the effect of several picosecond laser pulses on specially selected frequencies.

In the case of selective separation of an electron it is possible to obtain resolution on the order of 25 Angstroms which is limited basically by: the presence of the tangential component of the velocity of the emitted electron and the ratio of the indeterminacies. In certain cases after photoseparation of the electron, the formed positive molecular ion becomes unstable and arbitrarily splits off the proton [135]. On varying the polarity in the projector, it is possible together with the electron to direct the protons at the screen. The spatial localization of the drift point of the proton must be $(M/m)^{1/2} \approx 40$ times higher than for the photoelectron. This laser photoion microscope can have a resolving capacity which is entirely sufficient for resolution of the atomic parts of the structure of the molecule. The further increase in resolution of the photoemission microscopy as a result of selective photoionization of the molecule to heavier molecular ions is also possible.

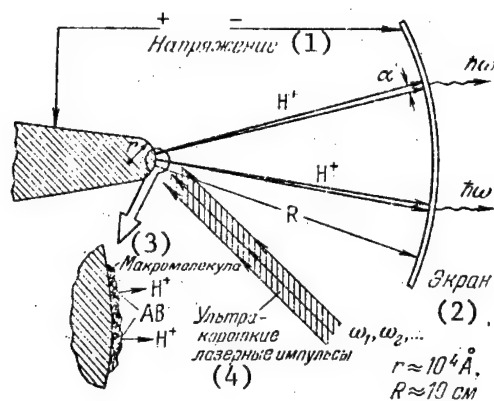


Figure 21. Possible schematic of the laser-ion microscope for spatial localization of the molecular bonds [17]

Key:

1. Voltage
2. Screen
3. Macromolecule
4. Ultrashort laser pulses

The idea of the investigated new approach to microscopy with atomic resolution is based on the combination of two important properties which usually belong to entirely different methods. The corpuscular (for example, electron) microscopy with quite high particle energy insures high spatial resolution. However, here the "contrast" of the image is automatically lost, for the variation of the particle energy as a result of interaction with the observed object becomes difficult to distinguish against a background of high initial particle energy. On the contrary, as the particle energy decreases the "contrast" of the image can increase sharply, and spectral selectivity becomes possible on observation of the image parts, but in this case the spatial resolution decreases automatically. The method of selective photodissociation offers the possibility of combining high selectivity (or contrast) of the optical channel with high spatial resolution of the "corpuscular (ion) channel." [17]

As one of the most important applications of the laser-ion microscope it is possible to point out the problem of determining the sequence of nucleotides in the DNA molecule carrying hereditary information about each individual organism. Here the problem consists in selective separation of the proton (or heavier molecular ion) either from the A-T pair of bases or the G-C pair. Of course, it is possible to test the realization of the approach based on the two-step selective IR+UV-excitation of the electron state through an intermediate oscillatory state of the selected nucleotide (see Chapter 8) and subsequent ionization of the electron-excited state. It is necessary that the selectivity of this process be sufficient for clear distinguishing of the pairs of A-T and G-C bonds. It is worthwhile especially to pay attention to the theoretical possibility of preliminary chemical "tagging" of any one pair of bases for facilitation of the selective excitation and ionization. For example, it is known [136] that one of the bases of the DNA (cytosine) selectively reacts with hydroxylamine. This reaction is accompanied by variation of the ultraviolet absorption spectrum of the

cytosine by a much greater amount than the standard difference of the base spectra. In this case the two-stage photoionization through the electron-excited state of the product of reaction of cytosine and hydroxylamine can turn out to be sufficiently selective. It is also possible to try selectively to "tag" one of the bases, for example, by the dye molecules having an absorption band in the visible range. In this case it will be sufficient to realize ionization of the selectively added dye molecules.

With an amplification coefficient of the laser ion projector $M=3 \times 10^5$ on the screen $R=10$ cm in size, a section of the linear chain of the DNA containing approximately 10^3 nucleotides (the spacing between adjacent nucleotides is 3.3 \AA), that is, a segment of the chain about 3300 \AA long will be depicted! Of course, for recording the sequence of nucleotides in long chains of DNA, the successive projection and "cross linking" of the images of successive sections are required.

For successful realization of the laser ion microscope for observation of biological molecules, it is necessary to investigate a number of quite complex problems: 1) selective excitation and ionization of the macromolecules adsorbed on the surface of a needle (see the first experiments in reference [138]); 2) the search for the selective dissociative ionization schemes causing separation of a proton or heavy molecular ions; 3) the spatial scanning of the point of the needle of the microscope along the chain of macromolecules, and so on. However, the solution of the problem of direct observation of the sequence of the nucleotides in the genes, including human genes, turned up enough such broad possibilities in the control of heredity that this field of selective laser photophysics appears to deserve the most serious attention.

In conclusion, I wish to express my deep appreciation to my colleagues at the laboratories of laser spectroscopy and the spectroscopy of excited states for a joint analysis of the problem of selective laser photophysics and photochemistry.

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PHYSICS AND MATHEMATICS

INDUSTRIAL USE OF RADIATION ADVOCATED

Moscow SOVETSKAYA ROSSIYA in Russian 2 Aug 78 p 4

[Article by Correspondent V. Ovcharov, Novosibirsk: "Restless Electrons. -- In the World of Science"]

[Text] Two ordinary yoghurt bottles were filled with wheat. One bottle, carefully sealed in plastic, contained seeds that were contaminated with grain-eating beetles. Or rather, the bottle contained the empty shells of these seeds, since the beetles did not waste any time in their glass prison. The grain in the other bottle, having the appearance of being gathered only today from the threshing floor, reflected that pure amber brightness which is usually a distinguishing characteristic of grain threshed late in August.

It was explained to me that the bottles contained indigenous (locally grown) grain. However, the grain in the first bottle was not subjected to special treatment while the grain in the second was treated.

The scheduled production experiment concerned with the application of industrial electron accelerators has been concluded at the Institute of Nuclear Physics [IYaF] of the Siberian Department, USSR Academy of Sciences. This experiment promoted a lively discussion among people. And yet: What is the relationship of nuclear physics to wheat and grain-eating beetles?

Statistics assert that millions of tons of grain are contaminated every year by various pests. At present, toxic chemicals are the chief weapon used against them. While this weapon is extremely expensive, it is not even that effective. More reliable methods of preserving grain stores had to be found.

The Siberian nuclear physicists proposed the application of accelerated electrons for this goal. Three years ago a group of specialists from IFaF, under the supervision of Candidate of Physical-Mathematical Sciences R.A. Salimov, began to equip an experiment at the elevator of the Siberian branch of the All-Union Scientific Research Institute of Grain.

V. G. Cherepkov, senior engineer of the Institute, standing at the control panel of the accelerator, remarked: "To conduct the projected investigation, contaminated grain was brought from southern regions of the country since such pests do not exist in Siberia. The result was excellent. The assembly processed more than 100 tons of grain per hour, and at the same time, fully provided the necessary exposure effect on the insects."

Decontaminating grain from insect pests is only one of many economic functions of industrial accelerators. Radiation technology--as shown by present practice--is following a most challenging direction of technical progress. For example, new technological processes based on the action of accelerated electrons are being developed. The Institute has a complete collection of sample products manufactured on the basis of radiation technology: thermostable polyethylene-insulated cables of various brands, all possible types of so-called thermo-sealing polymer pipes, hoses, etc.

"Thermo-sealing, which is acquired by many chemical substances through the action of fast electrons, is an indispensable property for the electrician," explained G. A. Spiridonov, deputy director of the Institute of Nuclear Physics. "It is also rather difficult to do without this new insulation during the installation of wiring on airplanes and ships. Watch this!"

He takes a piece of transparent sleeving, inserts several strands of wire, and lightly heats it with the flame of his lighter. The sleeving contracts from the action of heat and compresses tightly around the wire, literally in front of our eyes.

The range of application of new products can be remarkably wide. The economic effect of this, according to the calculations of specialists, is in the hundreds of millions of rubles.

Aside from purely materialistic benefits, radiation technology also promises significant qualitative advantages. Products that undergo processing by fast electrons become stronger and gain resistance to the action of external influences. Here is the signed testimony of I. B. Peshkov, director of the All-Union Scientific Research Design and Technology Institute of Cable Industry, which supports the above statements: "Radiological modification of thermoplastic polymer insulation for cable products permits a significant increase in their operating characteristics."

In general, everyone objectively supports progressive technological processes. However it is common that new concepts, despite their obviously evident advantages, are not accepted immediately. This is not so much because of psychological barriers, although their influence should not be discounted, but rather as a result of inflexibility, lack of engineering preparedness, and absence of a serious interest by the various organizations. Scientists and engineers of IYAF are forced

to promote the already ordered accelerators themselves, despite the existing contracts and ministerial decisions. And the efficiency of each scientific development increases many fold precisely through its subsequent operational utilization!

The story of the thermo-sealing sleeving and pipes is not in its first year. Before the question of their manufacture was finally resolved by Moscow Association Plastik, the workers of the Siberian Institute had to "roll out" 11 tons of such production on their "home-rigged" assembly. The product was appreciated especially by the customers who needed it. The agreement concerning the delivery of the accelerator was signed and the equipment was manufactured. However, the normal delays entered now into play. It is true, according to the Institute, that several weeks ago a group of specialists from the Association, headed by Deputy General B. P. Rashinin, finally visited the physicists.

The Okhtin Production Association Plastpolimer, near Leningrad, also does not distinguish itself in management efficiency. The Siberian Institute waited more than 6 months, after delivering an accelerator ordered by the Okhtin Association, for an invitation to participate in its assembly.

Naturally, an industrial electron accelerator is not a lathe. Its installation is considerably more complex. However, with the desire, it can be mastered fairly quickly. A brilliant example of this was demonstrated by the collective of the Hog Raising Complex Omskiy Bekon (Omsk Bacon): the Omsk complex required less than 4 months for the construction and complete preparation of the space occupied by the accelerator. And this was actually accomplished under rural conditions!

With the establishment of the accelerator facility at Omsk, the realistic application of the idea, previously proposed by Academician Budker, that waste waters can be purified by accelerated electrons is being investigated. The idea promises to remove from the agenda one of the most critical issues of contemporary agriculture--the purification of wastes from major livestock breeding complexes, and to make an important contribution protecting the environment.

In order to demonstrate the importance of the initiated experiments at Omskiy Bekon, I will quote a figure. More than 2,000 tons of water are utilized daily to clean the spaces holding manure. A veritable flood is created, which is by far not without harm. The use of existing methods to neutralize the harm of this flood is usually troublesome and expensive. Radiative equipment, as expected, allows to achieve this goal cheaper and quicker.

The widening sphere in the application of industrial accelerators brings with it the inevitable increase of their manufacture. However, in the opinion of specialists, it is at the present time wiser to manufacture

the accelerators at the experienced plants of the Institute, and correspondingly, expand its facilities. This consideration is dictated by more than economic motives.

Academician A. N. Skriskiy, director of IAaF, commented: "For a long time our institute, whose basic goal is fundamental investigations into the field of the physics of elementary particles and controlled thermonuclear fusion, has developed considerable effort towards the solution of contemporary applied problems of the national economy. We cannot discontinue fundamental and applied research projects. The latter of which should be the regular and logical continuity of the former."

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END